Vol. L **TABLE OF CONTENTS.** No. 6

(20 pages; no inset.)

	Page.
ENGINEERING NEWS OF THE WEEK	113
LEADING ARTICLES:	
New Terminal Station at Chicago for the C., R. I. & P. Ry. and the L. S. & M. S. Ry. (illustrated)	114
New Passenger Station at Lafayette, Ind.; Chicago, Indianapolis & Louisville Ry. (illustrated)	119
Metallic Packing; Principles of Design Essential for Successful Development (illustrated) Charles Longstreth	119
A New Trench Digging Machine (illustrated)	125
The Proposed Forth-Clyde Ship Canal, Scotland	125
Trench Excavating and Brickfilling Machine (illustrated)	126
Stremmatograph Tests of Fiber Strains in Rails Under Moving Locomotives. P. H. Dudley.	127
Effect of Water and Combinations of Sand on the Setting and Strength of Cement. E. S. Larned.	128
Report of the Commission of the Jerome Park Reservoir	129
The Cause of the Cementing Value of Rock Powders and the Plasticity of Clays. Allerton S. Cushman.	131
EDITORIAL COMMENT.—Pipe Galleries Along the New York Rapid Transit Railway—Engineers' Report on Jerome Park Reservoir	122
EDITORIAL.—Why Pave Residence Streets from Curb to Curb?	122
LETTERS TO THE EDITOR.—Riveted Joints Under Eccentric Loading: Henry Szlapka—Steel Dams for Storage Reservoirs: Charles R. Steiner—Relative Strength of Wet and Dry Concrete: E. R. Frink—The Testing of Bitumen for Paving Purposes: A. W. Dow—The Proper Age of Test Pieces for Accelerated Cement Tests: R. W. Lesley—Further Remarks on the Aesthetics of the Manhattan Bridge and Engineering Impressionism: George W. Colles—An Object Lesson in the Volume of Water Required for Fire Protection in Crowded Mill Yards: John R. Freeman (illustrated)	123

THE MANHATTAN SUSPENSION BRIDGE at New York city has received a further setback from the Board of Aldermen. On July 14 this body refused to confirm the action of the Board of Estimate appropriating $6,533,000 for constructing the bridge. Following this action of the aldermen the Board of Estimate practically repeated its former action by passing a resolution to appropriate $6,532,000 for the construction of the bridge. This last resolution was taken up by the Board of Aldermen on July 31 and again defeated by a vote of 41 to 25. It is now probable that no further attempt will be made to secure the appropriation until some months from now.

THE BLACKWELL'S ISLAND cantilever bridge across the East River received an appropriation of $3,868,000 for construction by vote of the Board of Aldermen of New York city on July 31.

LAMBETH BRIDGE, AT LONDON, crossing the Thames River, is to be rebuilt under the direction of the London County Council. The existing structure was built in 1861, and strengthened in 1887, but is not of sufficient strength for the present traffic. The bridge has grades of 5.3% to 4.4%, but the new structure will have maximum grades of 3.3%. It will have masonry piers with flat arches formed by steel girders or ribs, and the width will be 60 ft. The estimated cost for the bridge itself is $1,750,000; the approaches, river wall, design, supervision and contingencies bring the construction cost up to $2,310,000. The property to be acquired will cost about 2,050,000, making a grand total of $4,360,000.

THE ALASKA-SIBERIA RAILWAY project has again been brought to public notice, and is said to have the backing of American, Russian and French capitalists. A company has been incorporated in the State of Maine, and is headed by Mr. John J. Healy, the Klondike millionaire, who is interested in the Northwestern Transportation Co., of Chicago. Mr. de Lobel, of Paris, a member of the French Geographic Society, is also one of the incorporators. Mr. James H. Lewis, of Chicago, is attorney for the company. The tunnel under Behring Straits is the special feature of the project.

THE NEW YORK RAPID TRANSIT RAILWAY cannot be opened for traffic by January, 1904, as had originally been intended, but the opening will be delayed until about April. The delay is largely due to the strikes, especially on the stations and power house. A statement to this effect has been made by Mr. W. B. Parsons, Chief Engineer, and by Mr. J. B. McDonald, the contractor. Some of the strikes have lasted for five months. About 20 miles of track have been laid, and Mr. McDonald expects that by Jan. 1 the tracks will be completed from the Post Office to Harlem Bridge on the East Side, and to Washington Bridge on the West Side. After that there will be the finishing of the stations and the general cleaning up of the work before any traffic can be operated.

STEAM AND ELECTRICALLY HAULED TRAINS will compete on the Prussian State Railways during the next few weeks.

STEEL PASSENGER CARS are to be used for the local trains in the Pennsylvania R. R. tunnel at New York, and it is reported that an experimental car is being built at the company's Altoona shops. It is 50 ft. long, and the only inflammable material used is the rattan finish of the seats. These cars will be operated also over the lines of the New York subway. The Illinois Central R. R. is building some steel cars for suburban service.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the Cincinnati, New Orleans & Texas Pacific Ry., near Greenwood, Ky., on Aug. 1. Through a mistake in giving train orders, two opposing freight trains were allowed on the same section of track and collided. Both trains were double-headed. Six men are reported killed in the collision.——Two other serious accidents which occurred during the past week were also butting collisions. Two opposing passenger trains on the Atchison, Topeka & Santa Fe collided near Needles, Cal., on July 31, and several tramps stealing a ride were killed. On Aug. 3 a westbound freight and an eastbound passenger train collided on a piece of single track line on the Pennsylvania Lines West, near Hartford City, Ind. Many passengers were injured, some of whom may die. ——An exceptionally bad railway accident is reported from Central Europe. A cut of loaded cars broke loose from a train, near the town of Sucha, in Austrian Silesia, and ran back down a steep grade until it struck a passenger train. In the wreck resulting some 30 persons are said to have been killed.

A DYNAMITE EXPLOSION killed 20 people and seriously injured 70 more at South Lowell, Mass., July 29. The explosion occurred in a magazine of the United States Cartridge Co., the floor of which was being renovated. Newspaper accounts differ, but it appears that nitro-glycerine had leaked from the dynamite and had soaked into the floor. One of the workmen is reported to have dumped a can of liquid on a spot where fumes were rising; the liquid was an acid, and the explosion followed. This sounds rather improbable, but a fire from some source appears to have exploded the nitro-glycerine, which in turn exploded the dynamite and the powder in neighboring magazines.

CIVIL SERVICE EXAMINATIONS will be held Aug. 19, Sept. 4, Sept. 9, and Sept. 16 for inspectors of municipal work in New York city, as more fully set forth in our advertising columns.

A WATER SOFTENING PROCESS is to be established at Oberlin, O. Propositions have been made by two water treatment companies, but both plans involved extra pumping. The present plan of the Board of Trustees of Public Affairs is to utilize an existing reservoir, avoiding the extra pumping and also giving a longer time for sedimentation. The water will enter the bottom of one basin charged with the chemicals. It will then pass from the top of this basin to enter the bottom of a second basin, and from the top of this latter it will pass to the pump well. The water will be about a week in passing through the basins. Bids for this work will be received until Aug. 17. Mr. W. B. Gerrish, Superintendent of Water-Works, is Clerk of the Board of Trustees of Public Affairs.

A THAMES RIVER TUNNEL is to be built at London, England, to connect the districts of Rotherhithe and Shadwell. It will be 6,883 ft. long, or about 1¼ miles. Its outside diameter will be 30 ft., or 3 ft. more than that of the Blackwell Tunnel, completed a few years ago. The roadway will be 16 ft. wide, with two sidewalks 4 ft. 8½ ins. wide. The clear height over the center of the roadway will be 18 ft. 6 ins., reducing to 16 ft. over the curbs. The lining will require about 27,000 tons of cast iron. Plans and specifications are practically completed, so that bids will soon be invited. Work is expected to be commenced next spring, and finished in 5½ years. The cost will be about $6,700,000.

THE KRUPP STEEL WORKS, of Germany, have been reorganized and incorporated as a joint stock company, dating from June 30. The new company owns the steel works at Essen and Annen, a firing or gun-proving ground at Meppen, the Gruson works at Buchau, the Germania shipbuilding yard at Kiel, four blast furnace plants, smelting works and machine shops at Sayn, three coal mines, and a number of iron mines in Germany. It also has interests in iron mines at Bilbao, Spain, and in a Rotterdam steamship company. The principal products of the celebrated Essen works are large guns, projectiles and armor plates; also railway and shipbuilding material and heavy machinery. According to the census of April 1, 1903, the total number of persons employed by the Krupp Works was 41,013, of whom 4,046 were officials. Of these, 22,970 were at Essen, 6,620 in the coal mines, 3,062 at Kiel and 2,651 at Buchau. The wives and children of the employees increase the total to about 150,000 persons dependent upon the industries of this great company.

AMERICAN SHIPBUILDING for foreign commerce is reported by the Blue Book of the "Marine Review" to be at a standstill, not a single contract for a vessel for the foreign trade of the country having been let within the past two years. During the fiscal year ending with June 30, 1903, only 1,536 vessels, of 456,076 gross tons, were built in the United States, as against 1,657 vessels of 473,981 tons in the previous year. On the Great Lakes 41 steamers of 131,000 tons were built, as against 52 steamers of 161,797 tons for the previous year, which was one of the most active on the Lakes. On the seaboard, 18 ocean steamers were built, aggregating 101,471 tons. Four of these were for the trans-Atlantic service, and one for the trans-Pacific service. A few contracts have been placed for large steamers for the coasting service, but it is pointed out that this service differs from the foreign service in that only American vessels may engage in it. Since the war with Spain, naval contracts have been well distributed among the coast shipbuilders, and during the past year contracts for four battleships, two armored cruisers and two gunboats have been placed. Contracts for two more battleships are about to be given, and in addition the New York navy-yard is building one battleship. There are 41 warships now under construction, representing a displacement of 338,948 tons, a total of 415,500 HP., and costing for hulls and machinery $90,314,516.

A 10-IN. WIRE GUN on the Brown system was tested recently at Sandy Hook, and further official tests are to be made. Highly satisfactory results are reported from unofficial tests. The gun is 37½ ft. long and weighs 26½ tons. The projectile weighs 575 lbs., and the powder charge is 175 to 200 lbs. The maximum velocity given to the projectile is 2,503 ft. per second, but higher velocities are expected to be obtained by the use of high explosives. The gun has a tube built of longitudinal steel bars (curved in section to form the barrel), and this is wound with steel wire of square cross-section under high tension.

LAND RECLAMATION BY CONVICT LABOR is to be tried in Massachusetts. According to press reports offers will be invited by the State of Massachusetts for tenders of 800 to 1,000 acres of waste land anywhere in the State. As soon as such tenders are made and title cleared, gangs of convicts will be set to work improving the property. This is part of a scheme being worked out by the State authorities for the reforestization and reclamation of waste and barren lands throughout the State, from which, when improved, the Commonwealth may realize great sums, as has been the case in improving the flats of Boston harbor.

A FRENCH LOCOMOTIVE on the De Glehn four-cylinder compound system is to be tried on the Pennsylvania R. R. Engines of this system, of the eight-wheel and Atlantic types, are extensively used on the principal French railways for fast and heavy passenger service, and one is now being built for the Great Western Ry., of England. These engines have two outside high-pressure cylinders driving the rear pair of driving wheels, and two inside low-pressure cylinders driving the crank axle of the front pair of driving wheels. An engine of a somewhat similar design was built about a year ago for the Plant System of railways in Florida by the Baldwin Locomotive Works, but in this engine the four cylinders all drove the first driving axle. The French engine for the Pennsylvania R. R. will be delivered next year, and after some experimental service will be sent to the St. Louis Exhibition as a part of the railway company's exhibit. Eventually it will be put in regular service.

NEW TERMINAL STATION AT CHICAGO FOR THE C., R. I. & P. RY. AND THE L. S. & M. S. RY.

The city of Chicago has six large terminal stations for the accommodation of the numerous main lines of railway which enter that city, and one of these is now being replaced with a new station, in which the tracks are elevated above the street level, the approach forming a part of the track elevation system by which grade crossings are being eliminated throughout the city. This is the station owned and occupied jointly by the Lake Shore & Michigan Southern Ry. and the Chicago, Rock Island & Pacific Ry., and used also by the New York, Chicago & St. Louis Ry. The station is situated on the south side of Van Buren St., and covers the entire block extending south to Harrison St., between La Salle and Sherman Sts.

The station was opened for traffic on July 12, and the number of trains using the new station is about as follows:

	Main line.	Suburban.	Total.
Chic., Rock Island & Pac. Ry..	20	70	90
Lake Shore & Mich South'n Ry.	22	68	90
N. Y., Chic. & St. Louis Ry....	6	0	6
Total	48	138	186

The present Lake Shore & Michigan Southern Ry. Co. was formed by the consolidation of several other companies, the final consolidation taking place on June 22, 1869. The company that made the original entry into Chicago (on May 22, 1852) was called the Michigan Southern Ry., and this company became afterwards the Michigan Southern & Northern Indiana, which came into the L. S. & M. S. Ry. on June 22, 1869. The old Chicago station was built by the Michigan Southern & Northern Indiana Ry. jointly with the Chicago & Rock Island Ry., the right of way and tracks for some distance south being also jointly owned by the two companies. The date of its construction was about 1865 or 1866. The L. S. & M. S. Ry. inherited the ownership of the station at the consolidation above mentioned. The trainshed was opened on Dec. 18, 1866, and the office part of the headhouse was occupied in May, 1867. In the great Chicago fire of October, 1871, the station was very largely injured, but was at once restored upon the original plan. In 1887, the headhouse on Van Buren St. was built up to furnish more office acommodation, particularly for the Chicago, Rock Island & Pacific Ry. Co., and so it remained until demolished to make way for the building now in course of erection. This headhouse was a stone structure. The old trainshed was 131 ft. span, 535 ft. long, with stone walls and iron roof trusses.

The four main tracks of the Chicago, Rock Island & Pacific Ry. and the Lake Shore & Michigan Southern Ry. are built on the same 100-ft. right of way from Englewood north to the terminal station on Van Buren St., a distance of about six miles. Within the past few years, the tracks have been elevated from Englewood to 16th St. (5.5 miles), beyond which point they dropped to pass under the 12th St. viaduct and reach the railway yards, the tracks in the station being at the street level. This work was described in our issue of Feb. 22, 1900. Since the track elevation work was undertaken it has been seen that it was only a question of time before it would have to be extended to the terminal, thus eliminating the long and busy grade crossings at the yards and in front of the trainshed. This would necessitate the reconstruction of the terminal station. In 1901, the two railways decided upon continuing the track elevation work into the terminal and building an entirely new station, more suitable for their heavy and important passenger traffic. They also decided that the headhouse should be utilized as an office building for their own exclusive use.

Temporary terminal facilities were leased in the Grand Central Station, at Fifth Ave. and Harrison St., and the work of demolishing the old building was commenced Jan. 1, 1902. The stone was piled on the site, crushed and screened and stacked, to be used later in the concrete work of the new building. Ground was excavated to a depth of about 12 ft. below the street level (or 2 ft. above city datum), and 50-ft. piles were driven in rows and clusters for the foundations of walls and columns. The piles were cut off below the lake level, and upon them were built grillage footings of steel I-beams and concrete. The total amount of steel work in the station, including headhouse, trainshed, etc., is about 14,500 tons.

FIG. 3. NEW TERMINAL STATION AT CHICAGO: C., R. I. & P. RY. AND L., S. & M. S. RY.
Frost & Granger, Chicago, Architects; William Grace Co., Chicago, General Contractors.

GENERAL DESCRIPTION.

Fig. 1 is a plan of the first floor, at the lower or street level. Here the main entrance will be on Van Buren St., the vestibule opening into a lobby 96 × 118 ft. This lobby is the central feature of the entire station. Adjacent to it are the main ticket office, baggage checking room, information bureau, cab and omnibus office, dining room, telegraph and telephone offices, etc., while stairways and elevators give access to the waiting room, the trainshed and the office floors. The baggage room extends under the trainshed, and beyond it are the mail and express rooms, with five elevators in the baggage room, five in the express room, and one in the mail room. All these are large electric elevators designed to carry loaded trucks.

A noticeable feature is the provision made for the accommodation of cabs, omnibuses, baggage and mail wagons, etc., keeping them clear of the streets. The station extends to within 15 ft. of the building line of Van Buren St., leaving a wide sidewalk, but as the street is a narrow and busy thoroughfare no space is available here for vehicles to deliver passengers at the main entrance or to stand and wait for passengers. The two side streets are still narrower. The necessary accommodation for cabs and carriages is therefore provided under the La Salle St. side of the trainshed, a portion of the outer wall being omitted, leaving a space about 160 × 105 ft. open to the street, and obstructed only by the columns of the trainshed floor, which are 24 to 30 ft. c. to c. The inner side of this space is formed by the baggage room, in front of which is a broad concrete walk; at one end of this is a vestibule leading to the main lobby, and at the other end is a stairway leading directly to the trainshed. Adjacent to the vestibule are a cab office, and a waiting room and toilet room for the use of the cabmen.

Beyond the south end of the cabstand are rooms for emigrants, Pullman car porters, excess baggage, etc. Beyond this again is another broad space under the trainshed, open to the street and flanked by the mail and express rooms. This space is divided by a longitudinal iron fence with gates, so as to prevent theft of mail bags or express packages delivered by the wagons. Similar spaces for baggage, mail and express wagons are also provided under the Sherman St. side of the trainshed.

Fig. 2 is a plan of the upper or track floor, on which are the main waiting room and its auxiliaries. There is also a waiting room for passengers intending to take trains on the elevated railways, the downtown loop (used by all the elevated railways) passing along Van Buren St. and having a station connecting directly with the new terminal. Outside of the south end of the waiting room is a broad space or concourse 46 × 201 ft., shut off from the platforms by an ornamental glass and iron screen with gateways and booths for the ticket inspectors. In most stations the concourse or space between the waiting rooms and the train platforms is drafty and uncomfortable, but in this case the glass screen above noted will exclude drafts and smoke from the concourse and waiting room. The concourse serves as a distributing point, to break up the crowds. It is accessible by stairways direct from the cabstand and the main lobby, so that passengers need not pass through the waiting room, which is thus isolated from the business departments of the station.. This concourse has an arched ceiling on steel trusses, with a monitor roof having a skylight on the top and ventilating louvres in the sides. This skylight will be concealed by an ornamental glass screen.

Beyond the concourse are the tracks and platforms, there being 11 tracks, in pairs alternately 12 ft. and 24 ft. c. to c. The platforms extend beyond the trainshed, in order to accommodate very long trains, and these extensions are covered by umbrella roofs on light trusses and columns. Suburban trains will use the east side of the station, and the main platform on this side has an exit stairway (with turnstile), leading to Harrison St., for the convenience of passengers going to the south side of the city. The trainshed extends to the north side of Harrison St., across which the tracks are carried by an I-beam and Z-bar structure with solid floor of shallow construction, the beams being supported by transverse girders on three rows of columns in the street. On the south side of Harrison St is a building (under the tracks) containing the power plant for the station. In addition to the express rooms under the trainshed, there is a two-story brick express building, 450 ft. long, south of the power house and on the east side of the tracks.

HEADHOUSE.

The headhouse is 212 ft. 8 ins. long on the Van Buren St. front, and 156 ft. 10 ins. deep, with a height of 185 ft. from sidewalk to top of cornice. It is 12 stories high, but with a mezzanine floor and a high attic it is practically equivalent in height to a 15-story building. It is of steel frame construction, but the design of the steel work does not include any specially novel or important feat-

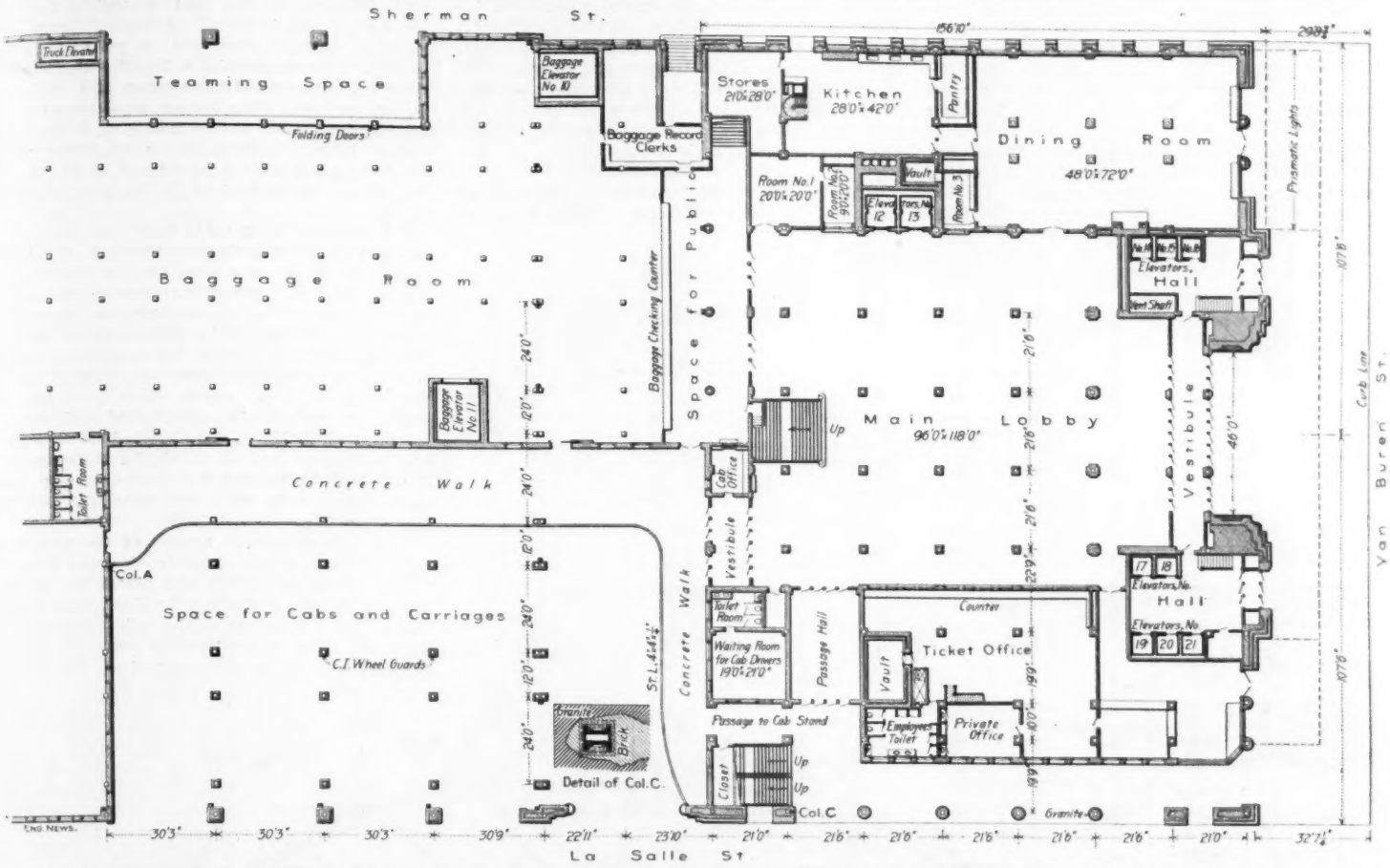

FIG. 1. FIRST FLOOR (STREET LEVEL) PLAN OF NEW CHICAGO TERMINAL STATION FOR THE CHICAGO, ROCK ISLAND & PACIFIC RY. AND LAKE SHORE & MICHIGAN SOUTHERN RY.

ures. The columns are of box section, built up of plates and angles) as shown by the detail cross-sections of columns and piers in Fig. 1. The loads on the columns vary from 500,000 lbs. to 1,000,000 lbs. There is no plate girder or truss work in the building, all girders, floor framing and roof framing consisting of I-beams. The floors and roof are of hollow tile construction. The station facilities occupy the first two floors, and above these are the offices.

The design of the building is plain and dignified, the principal architectural feature being the large archway over the main entrance. The exterior is of granite to a height of 47 ft. 6 ins.; the upper part is of Galesburg vitrified "Continental" brick of a dark reddish-brown color. with granite trimmings and terra cotta cornice. The mortar joints are not pointed flush, but are made hollow in order to avoid an appearance of flatness. The outer columns of the open spaces under the trainshed, forming the cabstand and arcade are encased in granite. The outer columns of the other open spaces under the trainshed are encased in pressed brick. Fig. 3 is a reproduction of a photograph of a wash drawing showing the general design of the building, as the site is so shut in that no satisfactory view of the station is obtainable. This illustration does not show the elevated railway, which passes across the front of the station.

In the basement is a vault for the storage of records, and on the first floor is the lobby already described, with ticket offices, baggage room, dining room, etc., as well as the kitchen, store rooms, and other miscellaneous offices. On the upper or track floor is the main waiting room, 106 × 108 ft., and 30 ft. high. The central portion of this is covered by a large skylight, beneath which is a decorated glass screen. Light is also supplied by large windows in the upper part of the great entrance arch, and by windows above the roof of the concourse. It is intended for use exclusively as a waiting room; it is not made a thoroughfare, and is quite independent of business departments of the station. It is accessible from the concourse, and from the lobby below, but passengers need not enter it in passing to and from the trains. Adjacent to it are the women's waiting room, smoking room, toilet rooms, lunch room, etc. On the mezzanine floor are the barber shop, and also reading and toilet rooms for the use of the conductors, trainmen, and mail clerks. These lower floors, forming the station proper, are fitted with a separate heating and ventilating system, including direct radiation and hot air, the fresh air (warmed in winter) being blown into the

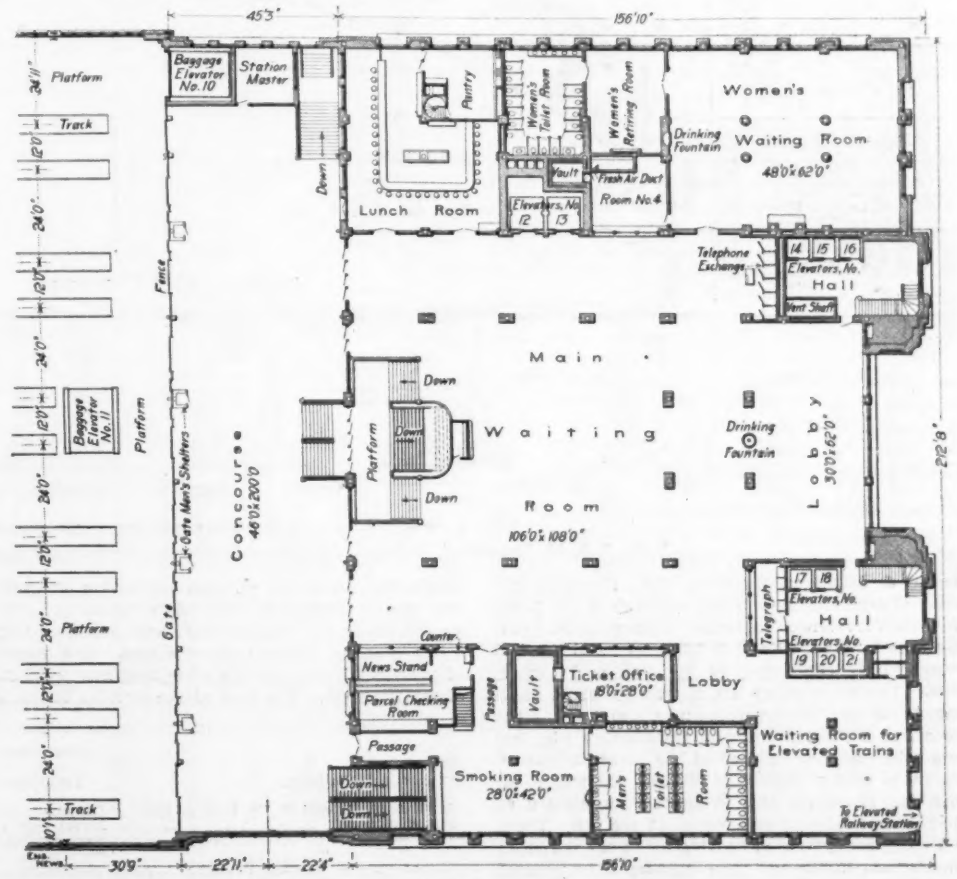

FIG. 2. SECOND FLOOR (TRACK LEVEL) PLAN OF NEW TERMINAL STATION AT CHICAGO.

rooms through ornamental grilles near the ceilings, and the foul air being drawn off through vents at the floor level.

Above the second floor the building is of U-shape, the skylight over the main waiting room forming the bottom of the court. All the floors above the station proper will be used for railway offices. The Chicago, Rock Island & Pacific Ry. Co. will occupy several floors, while the others will be occupied by the Chicago offices of the various Vanderbilt lines. These include the Lake Shore & Michigan Southern Ry., the Michigan Central Ry., the New York, Chicago & St. Louis Ry., the Cleveland, Cincinnati, Chicago & St. Louis Ry., the Indiana, Illinois & Iowa Ry., and the fast freight lines controlled by the Vanderbilt interests. The office floors are served by eight high-speed Otis electric elevators and a stairway. Each floor has a toilet room, and washbasins with hot and cold water are placed in the principal rooms. There is also a supply of filtered ice water for drinking purposes; this is kept in circulation so that there is always cold water at the tap. There is a complete system of heating by direct radiation from steam radiators. The lighting is by central groups or chandeliers, while numerous plugs in the ceilings enable drop lights to be fitted at any desired point. The windows are very large and are carried as high as the structural work will permit, so as to get a diffused light from the ceiling. There is a complete private telephone service throughout the building. All electric wires are carried up through the main ducts, and are easily accessible. There is a fireproof and burglar proof vault on each floor, while a large vault is provided in the basement for the storage of records, etc. The water tanks are in the attic, in order to avoid unsightly projections above the roof.

ROOF OF TRAINSHED.

The most important structural feature of the station is the trainshed, which consists of a series of pin-connected trusses, with curved top and bottom chords, springing from side columns and connected by longitudinal girders and purlins. Fig. 4 is a general plan and cross-section. The length of span is 207 ft., and the clear headway is 60 ft. above the rails. The rise of the bottom chord is 39 ft. 11½ ins., and the depth of arch at the center is 25 ft. Each truss is divided into 14 panels, varying in length from 10 ft. 3 ins. at the ends to 19 ft. 6 ins. at the middle. The first five trusses, however, have an additional panel of 4 ft. 11 ins. at the west end. The trusses are designed for a dead load of 35 lbs. per horizontal sq. ft. for steel, and 40 lbs. per linear sq. ft. for the roofing; while the live load is a wind pressure of 30 lbs. per sq. ft. and the snow load of 25 lbs. per horizontal sq. ft.

The accompanying table shows an interesting comparison of this trainshed with some other large structures of the same kind, but the new Chicago station and the Jersey City station of the Central R. R. of New Jersey are the only two having the trainshed roof carried by pin-connected trusses. The Jersey City trainshed has triangular trusses with curved bottom chords, the trusses being spaced 32 ft. 6 ins. apart. This main span is flanked on each side by a 36-ft. shed roof, making the total width 215 ft. The length is 27 ft. 10 ins. at the columns and 70 ft. 0⅛-in. at the center. It was built by Hedden & Sons, work being commenced March 20, 1888, and completed Dec. 10, 1889 (Eng. News, Oct. 6, 1888).

In the pin-connected trusses of the new Chicago station, the top chord is of double channel section, composed of two web plates ⅜ × 16 ins. and four outside angles ½ × 3 × 3 ins., with lacing bars at top and bottom. The web plates are 7¼ ins. apart. The bottom chord is composed of 6-in. eye-bars with 6-in. pin connections, but in the end panels the bottom chord consists of a pair of 10-in. channels, extending to the columns and serving as a knee brace. The vertical members are pairs of 10-in. and 12-in. channels, 7¼ ins. apart, having the webs parallel with the truss and the flanges connected by lacing bars. The

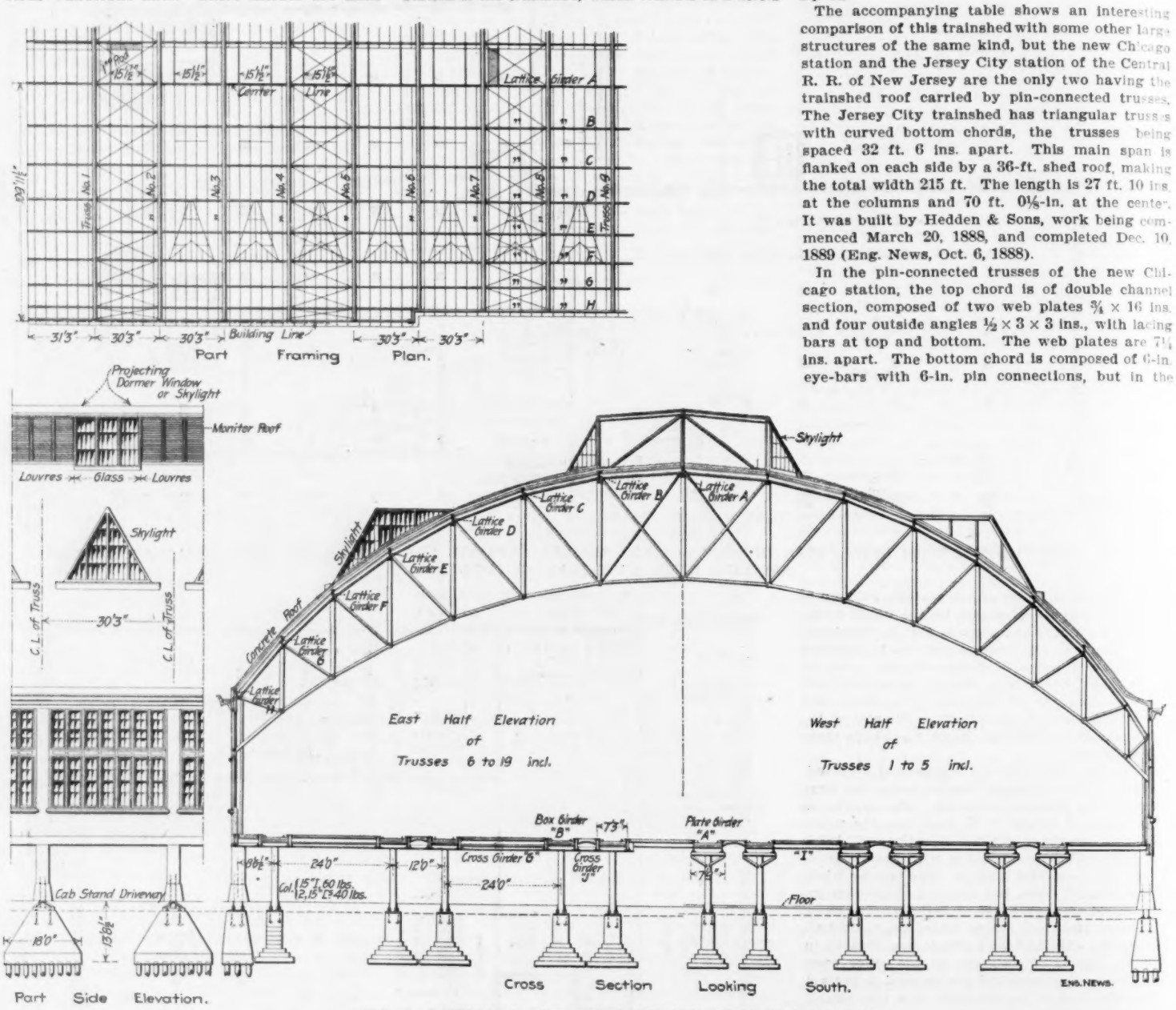

FIG. 4. PART PLAN AND CROSS-SECTION OF TRAINSHED.
E. C. & R. M. Shankland, Chicago, Consulting Engineers; American Bridge Co., Contractors.

Dimensions of Trainsheds.

Railway.	Location.	Type.	Span. ft. ins.	Width, ft.	Length, ft.	Clear height, ft. ins.	No. of tracks.
L. S. & M. S. and C., R. I. & P. Rys...	Chicago.....	1 truss.	207 0	....	578	60 0	11
Pennsylvania R. R.....	Jersey City....	1 arch.	252 8	256	777	86 0	12
" "	Philadelphia...	1 "	360 0	304	598	100 4	16
" "	Pittsburg.....	1 "	225 0	....	550	.. .	12
Philadelphia & Reading R. R.....	Philadelphia...	1 "	259 0	266	506	88 0	13
N. Y. Central Ry.	New York.....	1 "	200 0	200	650	96 0	12 } 19
		1 truss.	100 0	130	650	22 6	7 }
Boston & Maine (Southern).....	Boston.....	2 trusses	169 9	570	602	63 6	28
		1 truss.	228 6				
Union Station.....	St. Louis.....	5 truss spans.	90 to 141 ft.	601	700	20 to 74 ft.	30
Central Railroad of New Jersey.....	Jersey City....	1 truss.	142 4	215	512	27 to 70 ft.	12

flanges are cut away at top and bottom. The diagonal members are pairs of 4, 5 and 6-in. eye-bars. At each panel point the trusses are connected by lattice girder purlins 30 ins. deep, having their top flanges just above the top chord. Upon these are the rafters, 6-in., 7-in. and 8-in. channels, 5 ft. 0½-in. c. to c. The monitor roof framing is built up of angles, with a 10-in. longitudinal I-beam in the middle and a 10-in. channel at each side, these being connected by 8-in. channel rafters framed between them. The details of construction of one of the trusses are shown in Fig. 5.

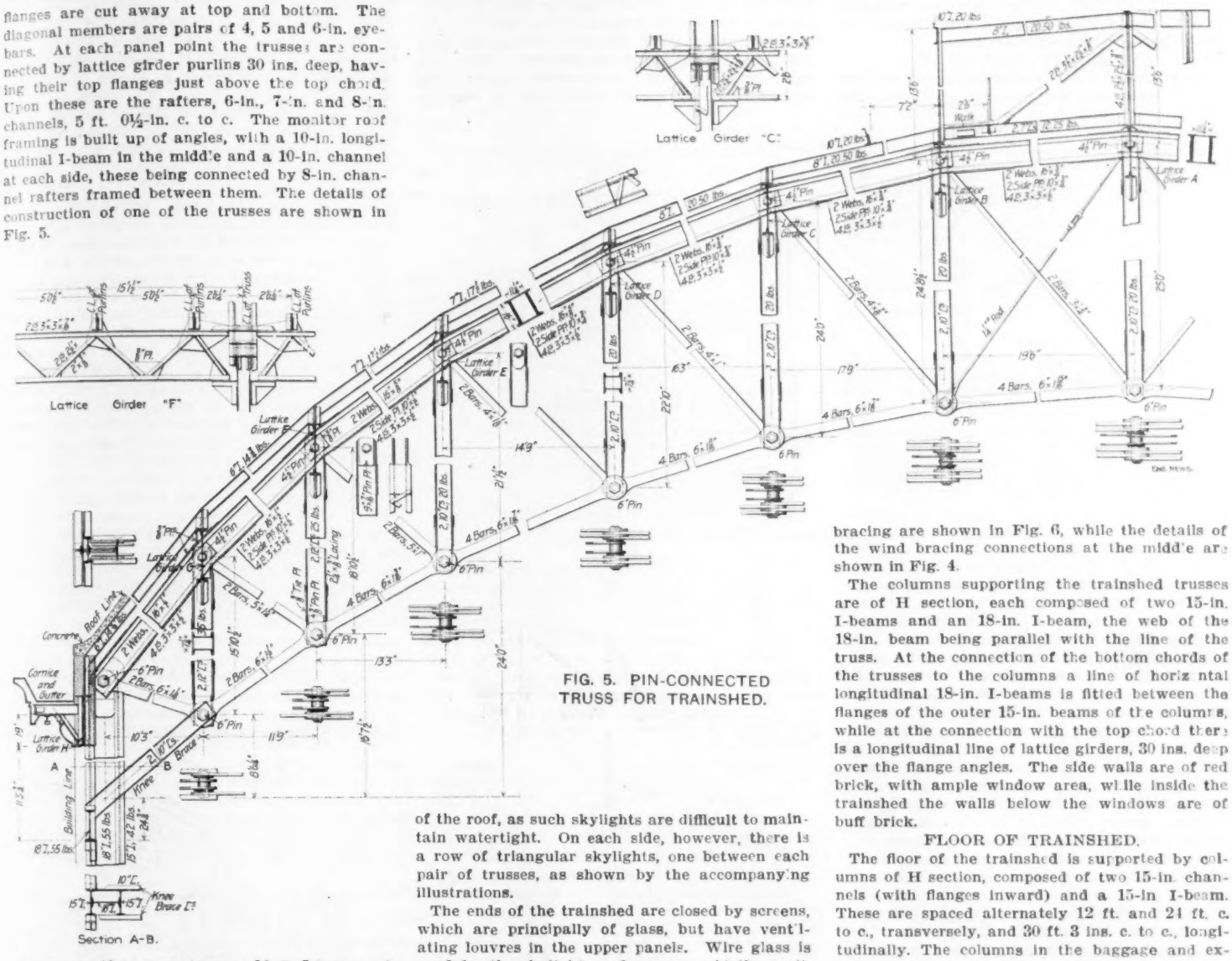

FIG. 5. PIN-CONNECTED TRUSS FOR TRAINSHED.

There are 19 of these trusses, 30 ft. 3 ins. apart, with a panel of 31 ft. 3 ins. at the north end between the north truss and the end screen. The total length is 578 ft. 5 ins. Six pairs of trusses are braced together by 1¼-in. diagonal rods, and this system of lateral bracing includes the two trusses at the exposed south end of the trainshed. Lattice girder purlins run between the trusses at the panel points of the top chords, and between each pair of trusses there are six lines of rafters, supporting a roof covering of 3-in. concrete slabs, 2 × 5 ft., reinforced by expanded metal. Along the top of the trainshed extends a monitor roof with projecting bays. These bays are fitted with glass, while the portions of the walls of the monitor roof between the bays are fitted with fixed louvres. There are no flat skylights on the slopes of the roof, as such skylights are difficult to maintain watertight. On each side, however, there is a row of triangular skylights, one between each pair of trusses, as shown by the accompanying illustrations.

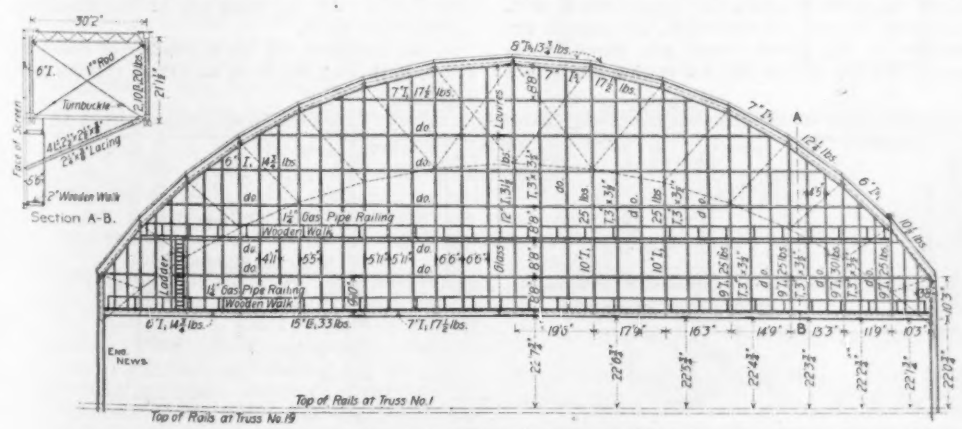

FIG. 6. SOUTH SCREEN OF TRAINSHED.

The ends of the trainshed are closed by screens, which are principally of glass, but have ventilating louvres in the upper panels. Wire glass is used for the skylights and screens. At the north end of the trainshed, which is sheltered by the headhouse, the framework for the screen is attached to purlins and girders projecting a panel's length beyond the truss. At the south end the framework is attached to the end truss and has to be well braced to resist wind pressure. The main verticals of the screen frame are 9, 10 and 12-in. I-beams, 11 ft. 9 ins. to 19 ft. 6 ins. c. to c. Between the vertical beams are lines of horizontal I-beams, laid flat, while the lower ends of the verticals are connected by a line of 15-in. channels riveted against their faces. The main panels formed by the vertical and horizontal I-beams are subdivided by vertical T-bars, two in each panel. Inside the screen are two footwalks for the cleaners, etc. The south screen and its wind bracing are shown in Fig. 6, while the details of the wind bracing connections at the middle are shown in Fig. 4.

The columns supporting the trainshed trusses are of H section, each composed of two 15-in. I-beams and an 18-in. I-beam, the web of the 18-in. beam being parallel with the line of the truss. At the connection of the bottom chords of the trusses to the columns a line of horizontal longitudinal 18-in. I-beams is fitted between the flanges of the outer 15-in. beams of the columns, while at the connection with the top chord there is a longitudinal line of lattice girders, 30 ins. deep over the flange angles. The side walls are of red brick, with ample window area, while inside the trainshed the walls below the windows are of buff brick.

FLOOR OF TRAINSHED.

The floor of the trainshed is supported by columns of H section, composed of two 15-in. channels (with flanges inward) and a 15-in. I-beam. These are spaced alternately 12 ft. and 24 ft. c. to c., transversely, and 30 ft. 3 ins. c. to c., longitudinally. The columns in the baggage and express rooms have triangular brackets at the top, carrying longitudinal lines of single-web plate girders 33 ins. deep. The columns in the open spaces for the cabstand, etc., are left without any such projections, as these would be inconvenient and even dangerous. Instead, a 27-in. box girder is placed across the top of the column, and framed against its ends are longitudinal 33-in. box girders. The wide main platforms are carried by transverse 15-in. I-beams 5 ft. apart, supported by angle brackets on the webs of the plate and box girders, the tops of the beams being 4½ ins. below the tops of the girders. Between the beams are concrete arches, and the concrete is carried up flush with the tops of the girders. The flooring for the tracks consists of the Pencoyd flooring with transverse rectangular troughs, built up of 6-in. Z-bars, and resting on continuous shelf angles on the plate girders. This is covered with stone ballast in which are embedded oak ties 6 × 8 ins. for the 80-lb. 5-in. rails. The tops of the rails are flush with the tops of the longitudinal girders. The narrow platforms between the tracks are formed by longitudinal concrete arches of 5 ft. 4 ins. span, 6 ins. thick at the crown. The general arrangement is shown in Fig. 4, while Fig. 7 shows the details of construction.

At the stub ends of the station tracks will be plate girder bumper beams, Fig. 8. Two longitudinal girders 15 ins. apart, 48½ ins. high and 4 ft. 9¼ ins. long, carry the striking plate, and are supported at the track face by triangular brackets. At the bumpers of the tracks over the columns having longitudinal plate girders supported on brackets, the heel of the bumper is directly over the column, by which any strain due to shock is directly resisted. At the tracks carried by box girders on cross girders on the columns, the bumpers are not directly over the col-

umns, and their tail ends are therefore supported by three transverse 20-in. I-beams framed between the main girders, as shown.

POWER PLANT.

One of the specially interesting features of the station is its very complete power plant. The power house is entirely separated from the station proper, being on the south side of Harrison St., and extending the full width of the right-of-way, between Sherman and La Salle Sts. It is located under the tracks, as already noted. This building is 150 × 212 ft., and contains all the plant for heating, ventilating, lighting, water supply and elevator service. There will be no fires in the headhouse, except those in the kitchen ranges.

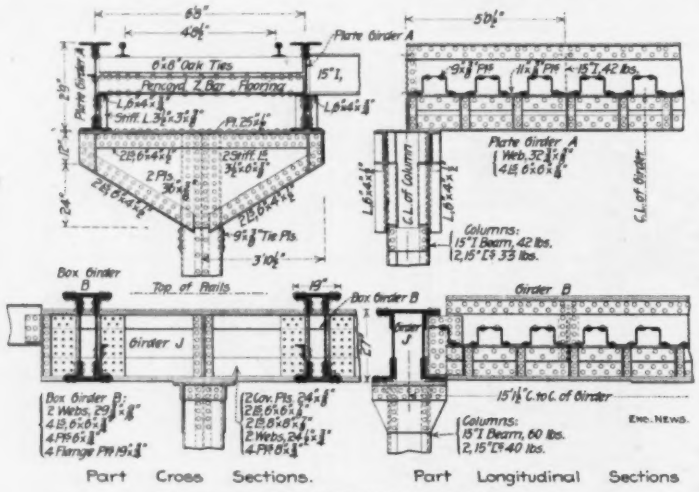

FIG. 7. FLOOR SYSTEM OF TRAINSHED.

In the boiler room are five Cahall horizontal water-tube boilers of 250 HP., and space is provided for a sixth. They are fitted with Green traveling chain grates, giving very complete combustion, so that very little smoke is emitted from the brick chimney, which is 175 ft. high, with a 7-ft. flue. The coal bunkers, of 400 tons capacity, are on the west side of the boiler room, and the coal is discharged from hopper bottom cars on a track directly over the bunkers. For lump coal, there is a motor-driven crusher, with a conveyor to distribute the crushed coal to the bunkers. The coal conveying system includes a traveling electric elevator suspended from an overhead rail, or runway, and running the entire length of the boiler room. This is loaded by means of gates at the bottoms of the bunkers, and discharges the coal into chutes in front of each boiler. The ashes are elevated from the boiler room floor to an ash bin above the end of the coal track, and from this the ashes can be discharged through spouts into the empty coal cars. The ash elevator runs in a brick shaft built as a part of the chimney. The coal handling plant was installed by the Link Belt Machinery Co., of Chicago.

The boiler room floor is about 6 ft. below the level of the street, and the ashpits are 3 ft. lower. As the floor is very nearly at the sewer level, subsoil drainage is provided, the water being lifted to the upper level drainage system by Yeoman bilge pumps. A similar arrangement is provided for draining the basement of the main building or headhouse.

The water supply may be drawn from an artesian well in the power house or from the city mains. The well is 8 ins. diameter and 1,600 ft. deep, and the water is pumped by the air-lift system and discharged into an open tank. The principal pumps are of the motor-driven triplex type, manufactured by the Stilwell-Bierce & Smith-Vaile Co. In the power house is a triplex pump taking water from the well tank or the mains, and delivering to the tanks in the attic of the headhouse. An auxiliary pump is installed in the basement of the latter, and draws its supply from a separate city main. The principal boiler feed pump is of the same pattern, and there are two steam pumps in the boiler room as a reserve for any of the electric pumps. There is an 18-in. carbonic-oxide compressor in the basement of the headhouse, supplying cold water to drinking fountains and faucets throughout the building, and also furnishing cold storage in connection with the restaurant. Two motor-driven cross-compound Ingersoll-Sergeant air compressors, with capacities of 1,000 and 500 cu. ft. per minute, are installed in the power house, and supply compressed air for the air-lift, for testing air brakes in the yard, for cleaning cars in the coach yard, and for various purposes in the power house.

Electric current is used for operating the pumps, grates, air compressors, etc., the passenger and freight elevators, and for the signal and interlocking plant, as well as for lighting purposes. There are three of the Western Electric Co.'s 220-volt direct-current generators, each directly connected to a cross-compound non-condensing engine built by the Buckeye Engine Co. One generator is a 500-KW. machine, running at 150 revolutions, and having an engine with cylinders 20 × 30 and 36 × 30 ins. The others are 250-KW. machines, running at 200 revolutions, and their engines have cylinders 15¼ × 18 and 28½ × 18 ins. There are two compensator sets, used in connection with a three-wire system.

The electric lighting will include about 7,000 incandescent and 225 arc lamps. In the station portion of the headhouse (which comprises the two floors on the street and track levels) there are approximately 1,000 incandescent lamps, and the trainshed is lighted by 108 arc lamps. The baggage and mail rooms under the trainshed, the driveways, cabstand, concourse, etc., are lighted principally by 100 arc lamps. The same plant will also supply current for lighting the signal lamps, the arc lamps in the yard, and the lamps in the express building south of the power house.

The office portion of the main building is heated by direct radiation. The station portion is heated mainly by means of fans discharging hot air through ornamental grilles in the upper part of the walls; while radiators are also used at exposed points. The entire heating system is supplied with exhaust steam from the power plant, and operated on the Warren-Webster vacuum circulation system. The temperature in the offices is controlled by thermostats, the radiators having no hand valves. The returns from the heating system are collected into a tank in the basement of the headhouse, and thence pumped to the power house, being discharged into a Cochran open heater which is used in connection with a Sorge-Cochran purifying system. The total heating system in the station and offices includes about 60,000 sq. ft. of radiation. The ventilation is secured by exhausting the air through vents at the floor level

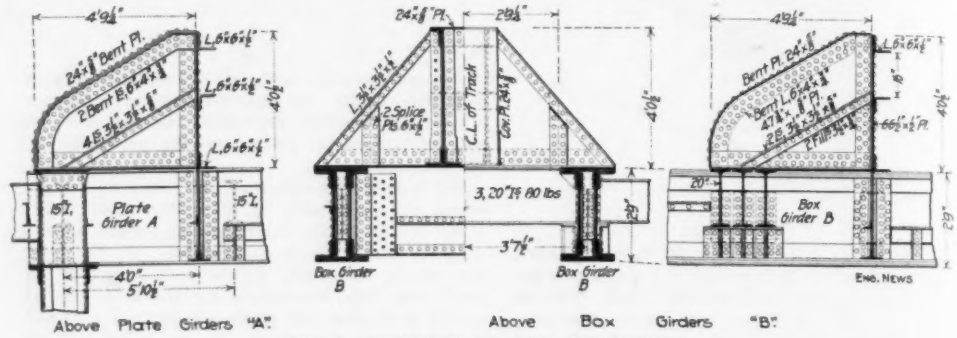

FIG. 8. BUMPERS AT END OF TRACKS.

headhouse, and also furnishing cold storage in connection with the restaurant. Two motor-driven cross-compound Ingersoll-Sergeant air compressors, with capacities of 1,000 and 500 cu. ft. per minute, are installed in the power house, and supply compressed air for the air-lift, for testing air brakes by means of a fan driven by a 50-HP. motor in the basement of the headhouse, and two smaller fans in the attic for office floors. There is also a motor-driven fan for ventilating the boiler and engine rooms. All the fans are of the American Blower Co.'s make.

In the trainshed are set a number of cast-iron boxes, flush with the floor, and these contain pipe

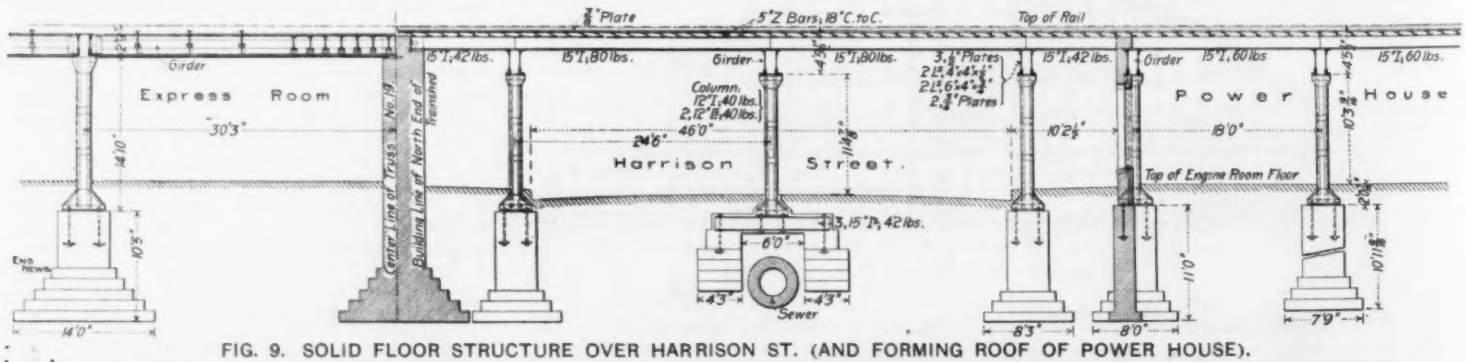

FIG. 9. SOLID FLOOR STRUCTURE OVER HARRISON ST. (AND FORMING ROOF OF POWER HOUSE).

and electric connections, so that any car or train can be supplied with compressed air, steam or electricity.

HARRISON ST. BRIDGE.

Across Harrison St. the tracks are carried by a solid unballasted floor of shallow construction, giving a headway of about 14 ft. Three rows of

columns carry box girders parallel with the street and upon these are 15-in. 80-lb. I-beams, 15 ins. and 18 ins. c. to c. Across these again are 5-in. Z-bars, 18 ins. c. to c., supporting a ⅜-in. deck plate to which the rails are bolted. This same type of floor extends south over the power house, and to a heavy concrete retaining wall, beyond which is the ordinary track elevation work, with a solid bank retained by vertical concrete walls.

FIG. 1. NEW STATION AT LAFAYETTE, IND.; CHICAGO, INDIANAPOLIS & LOUISVILLE RY.

C. J. Warren, Architect, Boston, Mass.; W. F. Stilwell & Co., Builders, Lafayette; W. A. Wallace, Asst. Engr., C., I. & L. Ry., Chicago.

This floor arrangement will allow tracks and switches to be placed in any desired position, and to be rearranged at any time as may be desired. The row of columns in the middle of Harrison St. comes directly over a brick sewer. Footings were built on either side of the sewer and spanned by three 15-in. I-beams under each column the beams being embedded in concrete. This is shown in Fig. 9.

ERECTION.

In building the headhouse, the erection of the steel work and handling of the stone, etc., was effected by means of seven stiff-leg derricks of 10 tons capacity, set on the steel floor framing. The derrick for erecting the steel work had a 70-ft. boom, which could be lowered to a horizontal position, and was operated by a 22-HP. engine.

The traveler used in erecting the trainshed roof was a timber structure consisting of nine bents parallel with the tracks, and framed into these were three transverse frames. Seven of the bents started at the ground line, resting on sills which were supported on oak rollers. The third bent from each end was omitted in the lower panel. This was done in order to form two openings to admit cars with material, as it was intended to begin work at the north end of the train shed. As a matter of fact, however, work was commenced at the south end, so that the cars delivered material at the working face of the traveler without passing under it, and the openings were thus unnecessary. The traveler was equipped with three boom derricks on the top, each operated by a 25-HP. engine. The weight of the traveler was about 300 tons, and it was carried on 84 oak "sad rollers," 10 ins. diameter.

The roof of the trainshed was erected in 2½ months. One trusss was erected in nine hours, and the working force could erect three trusses and all the purlins, rafters, skylights and dormers for these in one week, providing the weather conditions were favorable. Storms and severe cold, however, delayed the work, but under favorable conditions the whole roof could have been erected in about seven weeks. There are about 2,200 tons of steel in the roof.

ARCHITECTS, ENGINEERS AND CONTRACTORS.

The architects for the station were Frost & Granger, and the designs for the structural work of the trainshed and headhouse were prepared for them by E. C. & R. M. Shankland as consulting engineers. Charles G. Armstrong & Co. were also consulting engineers for the architects in the design of the power plant. The general contract was let to the William Grace Co., and the steel work was built by the American Bridge Co. The erection of all the steel work, including both the headhouse and trainshed, was let to Oscar Daniels; and the L. H. Prentice Co. had the contract for the heating and ventilating plant. All the above firms are located in Chicago. The interlocking switch and signal plant in connection with the station and its approaches is being installed by the Taylor Signal Co., of Buffalo. In the construction of the new station each of the two railway companies which are joint owners is represented by its own Chief Engineer: Mr. E. A. Handy of the Lake Shore & Michigan Southern; and Mr. W. E. Dauchy (later succeeded by Mr. J. F. Stevens) of the Chicago, Rock Island & Pacific Ry. Mr. V. A. Matteson was Superintendent of Construction for the architects, and Mr. F. M. Gardner was Engineer for the contractors.

NEW PASSENGER STATION AT LAFAYETTE, IND.; CHICAGO, INDIANAPOLIS & LOUISVILLE RY.

An example of a small but attractive railway station is afforded by the new station of the Chicago, Indianapolis & Louisville Ry., at Lafayette, Ind. Fig. 1 is a general view, and Fig. 2 a ground plan of the station, giving a good idea of the interior arrangement. The waiting room fronts on the street and on the track. The building is of Indiana oölitic limestone, and its cost was about $15,000. The station looks rather peculiar in that it has no platform shelter. The reason for this is that the railway runs along a public street and the sidewalk forms the platform. The light side of the building in Fig. 1 fronts the track, while the side in shadow fronts upon a cross street.

The plans were prepared by Mr. Clinton J. Warren, architect, of Boston, and the builders were W. F. Stilwell & Co., of Lafayette, Ind. For the plan we are indebted to Mr. W. A. Wallace, Assistant Engineer, C., I. & L. Ry.; while the photograph was kindly furnished by Prof. Wm. D. Pence, of Purdue University, Lafayette, Ind.

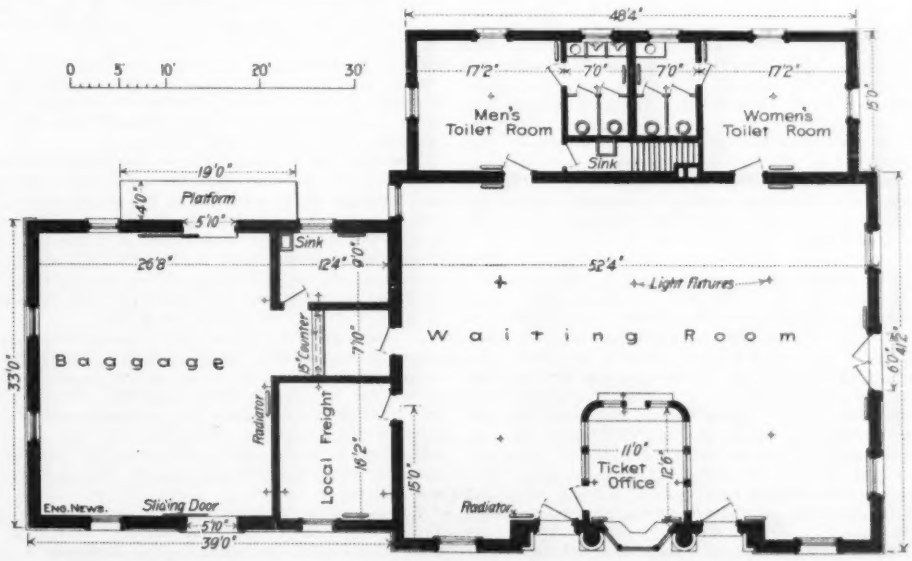

FIG. 2. GROUND PLAN OF NEW STATION AT LAFAYETTE, IND.

METALLIC PACKINGS; PRINCIPLES OF DESIGN ESSENTIAL FOR SUCCESSFUL DEVELOPMENT.*

By Charles Longstreth, Assoc. Am. Soc. Naval Engineers.

Metallic packings attracted attention at a very early date in the history of the steam engine. Edmund Cartwright's patent of 1797 specifies the following:

The piston rod is also packed upon the same principle, that is to say, solely with metal which is thus done: The top of the cylinder being made true and smooth, a flat ring, cut into segments, lies upon it and embraces the piston rod, towards which it is pressed inward by springs; this ring is inclosed by another divided into segments, and to which it is pressed inward by springs. The segments of the inner and outer ring must be so placed as to break joint. The rings are covered by a third, which is held down by any adequate pressure, as in the piston; the whole may be encircled by a box for holding oil, etc.

This covers the principal points of quite a number of the well-known packings of the segmental block type in use at the present time.

Also Richard Trevithick's patent of 1815 particularly alluded to a combination of fibrous and metallic packings. He also describes a design that is practically the basic principle of the present double packings, that is, two stuffing boxes with intervening space. At that early date he was impressed with the friction caused by the fibrous packings, and used his double packing with the idea that he could overcome some of this friction by allowing steam or water to occupy the space between the two packings.

John Barton's patent of 1816 and drawings which accompany it, plainly show a very ingenious segmental block packing, which would probably be considered a good one even at the present day.

From what we read of these early English patents, it is quite surprising that metallic packings were not more generally used at an earlier date. The only reason given for their disuse was probably the imperfect condition of piston rods which would not permit the use of any form of metallic packing, owing to the irregularity of surface which became more noticeable on account of the long strokes then in use.

PURPOSES AND REQUISITES OF A SATISFACTORY PACKING.

The purposes of a piston-rod or valve-stem packing are to prevent leakages of steam both along the rod or stem.

*Reprinted from the Journal of the American Society of Naval Engineers, May, 1903.

and also between and around the packing, and to do this with minimum pressure and friction. At the same time the packing should not be designed to act as a guide for the rod or stem, thus partly usurping the function of the crosshead guide. The packing, on the contrary, should be designed so that it will be sufficiently flexible to allow slight lateral movement of the rod while remaining steam-tight. It is to the satisfaction of this latter requisite that the more recent designs of metallic packing owe their superiority over the old-fashioned fibrous or the early designs of metallic packing.

CHARACTER OF PACKING DEPENDENT UPON NATURE OF MOTION OF WORKING PARTS.

In designing packing, we must consider the character of the rods or stems to be packed—that is, whether the moving parts have a rotary or reciprocating motion. If the moving parts require no guiding, as in the ordinary type of steam pumps, the problem is a comparatively simple one. If the moving part has a slight vibratory as well as a reciprocating motion, then the problem becomes quite difficult to solve. This vibratory motion, being caused by the slight difference in diameter between the piston and cylinder, as well as by the play between crosshead and guide changes at every point of the stroke and varies with every position of the connecting rod. Slight vibratory motion may also be caused by the roll or pitch of the vessel, in the case of marine engines, and while the amount of such motion may seem trivial to some, it bears a very important relation to the wear of both packings and rods.

CHARACTER OF PACKINGS; RIGID VS. FLEXIBLE.

In order properly to classify packings to meet the varying conditions to which they are subjected we should di-

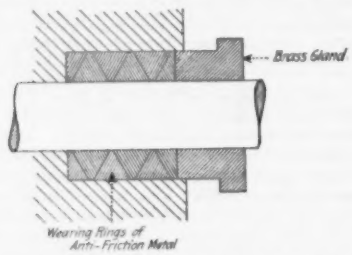

Fig. 1. Rigid Packing of Male and Female Ring Type.

vide them into two general classes: (a) Rigid packings of the male and female-ring order. (b) Flexible packings, which can again be subdivided into two types—the segmental or block design and the conical-ring form.

RIGID PACKINGS.—This design is illustrated by Fig. 1. It prevents the leakage of steam around the stuffing box, by having the outside of the female rings pressed against the stuffing-box wall. In order to prevent the leakage of steam along the rod, the inside of the male rings is pressed toward the rod. The force holding these rings against the various surfaces is exerted by pressing the gland against the end of the rings. As ordinarily designed, it will be observed that the great trouble with such packings is to secure a steam-tight joint against the wall of the stuffing box, as there is no wear there. This can only be accomplished by producing great friction and pressure against the rod, and as the packing fills the entire space between the walls of the stuffing box and the rod, it does not allow any of the vibratory motion previously alluded to.

Where vibratory motion exists and this class of packing is used, the packing is compelled to do a large amount of the guiding that should be taken up by the walls of the cylinder and the guides. The absurdity of attempting to do this part of the work with a surface so small and a material so soft as that of the packing will be at once apparent to the engineer. It can readily be seen why piston rods fitted with this type of packing require such an excessive amount of lubrication to prevent the rods from running hot. Frequently with packings of this type, rods become so hot as to melt the anti-friction metal and cause it to run from the stuffing box. This packing, therefore, can only be used with success on valve stems and rods of auxiliaries, as well as on appurtenances to boilers and engines.

It is possible, however, to design this packing so that the amount of pressure against the rod may not only be reduced, but at the same time the leakage around the wall of the stuffing box may be stopped. It goes without saying that this packing may be used where the motion of the rod or stem is comparatively small or infrequent.

It is usual in most cases to place one turn of fibrous packing under the gland; often it is claimed that this turn of soft packing is for lubricating purposes, but as a matter of fact the manufacturer of the class of packings under consideration knows that it is really placed there to prevent the slight leakage of steam due to improper design of packing. Some properly-designed packings of this character may be used with a turn of soft packing while they are being broken in. After the metallic packing has worn down to a bearing the soft turn may be removed, since the metallic packing will be found to be steam tight. Packings of this design are of very early origin, the first of them being used about 1843.

FLEXIBLE PACKINGS.—The succeeding types of packings, which may be considered as designed on engineering principles, differ entirely from the foregoing. The new designs do not attempt to fill the entire stuffing box, as steam is allowed to enter the stuffing box and the packings thus have a chance freely to acquire a vibratory motion. The steam leakage around the walls of the stuffing box is duly taken care of by metal or other gaskets under glands, and by sliding faces ground steam tight. The gland is thus pulled up tightly against the intervening joint and the cylinder head, and all the adjustment takes place from the inside.

The segmental ring or block form of flexible packing is shown by Fig. 2. These packings are usually metallic segments, although it is often the case that they are simply blocks of metal held fairly close to the rod by some form of pressure—that is, either by means of a spring, by the pressure exerted by the steam, or by a combination of both these forces.

There are probably more different designs of this class of packing than of any other, since such forms may be designed by people of comparatively little experience, and give fairly good satisfaction where moderate steam pressures are used.

Those in charge of marine machinery should be impressed with the fact that the quality of the steam supplied to the engines will have a very important influence upon the life of the packing. There is no doubt but that even a slight amount of water in suspension in the steam brings with it from the boiler some gritty substance: While this amount may be apparently of an inconsiderable nature, it is sufficient to greatly increase the wear of the packing.

The relative life of the packing when using both dry and saturated steam was evidenced in the case of engines of sister ships belonging to the same line, running on the same service and carrying the same pressures. On the high-pressure rod of one ship, where no care was taken to secure dry steam, the life of the packing averaged about thirty days' wear. On the engines of the sister ship, where care was taken to secure dry steam, the same packing has been in use for several years.

The principal objection to segmental packings is that they are expensive to manufacture and necessitate care in maintenance. They are generally of a complicated nature, since they comprise a large number of springs, segments and rings. As the packing is forced to the rod by the steam pressure, the friction on the rod or stem increases proportionally with increase in boiler pressures. In other words, it is almost impossible to use packings of this character on a triple-expansion engine and obtain anywhere near the same length of wear from the packings for the three different cylinders; the high wearing out most rapidly, the intermediate wearing out next rapidly, and the low lasting the longest.

The last type of packing to be considered is usually known as the conical ring, and is shown by Fig. 3. This type of packing has given better satisfaction under adverse conditions than all others, and is the packing used on 90% of the locomotives running in the United States. This in itself is an evidence of its ability to run under adverse conditions with little repair.

The principle of this packing is that conical, soft-metal rings are pressed against the rod, and thus packing is accomplished by the rings being forced into a solid cup bored to conform to the outside of the rings. These rings are pressed into the cup partly by a spring, but principally by the steam itself. If the pressure of steam were constantly on the packing the springs would be unnecessary, as the springs are used merely to hold the packing in place while steam is shut off the engine.

In order that this packing shall be satisfactory, the cup must not be allowed to touch the wall of the stuffing box at any time. The proper design as well as the character of material of these packings is therefore the most difficult problem to be solved in the packing business, as the mixture of metal in the rings, as well as the form of the outside of the rings, must be such that the packings will merely prevent the leakage of steam and not cause excessive friction.

Where properly designed, these packings can be made to give approximately the same length of wear on all the rods of a multiple-expansion engine. However, in practice it has been found that this is not entirely desirable, and so, when usually designed by first-class manufacturers, the high-pressure packings wear out a little while before the intermediates and low.

It will be often noticed that the shape of rings in packings of this character on the high-pressure rods is slightly different from that on the intermediate and low. In order to permit cheap and rapid repairs, it is desirable to have a uniform quality of metal used for the rings, while it is also necessary to have the form of rings balance differences in pressure.

With this type of packing there is absolutely nothing that comes in contact with the rod except the white-metal rings. The glands, neck bushings, cups, followers, etc., being bored considerably larger than the diameter of the rod or stem, and as the rings are made of soft metal and properly designed, they will cause very little friction and wear on rods.

Many experiments and tests have lately been made with packings of this nature, and where proper provisions are made to allow the rings and their enclosing cups to move freely with the rod they have been universally satisfactory. In order to allow the cup completely to accommodate itself to this condition, it is advisable to provide a ball joint in addition to the sliding face previously alluded to. A hot rod from packings of this type is practically unknown, and in railway service, where at the present time all details of this kind are apt to be carelessly handled, that they operate with any degree of success at all, speaks volumes for their design. In addition to the above, the advantages of this type are that wearing parts are inexpensive and easy to replace.

The disadvantage of these packings, if it can be called a disadvantage, is that they will not work properly on a rod unless the rod is cylindrical. When packings are applied, if the rod is cylindrical, even though it is grooved, these packings in a short time will become steam tight. There are many cases on record of extremely long service without renewals of this class of packing. Cases are on record of ten years' run, although the average life may be taken as from two or five years, and then the packings may be put in as good condition as they were when new, by merely supplying a few inexpensive soft-metal rings.

ENGINE EFFICIENCY DEPENDENT UPON CHARACTER OF PACKINGS.

It is remarkable how little attention has been paid to this engineering subject and the ignorance of proper principles upon the part of engineers. It really requires very little cross-section of rings to do this work of packing, provided everything is properly designed; and the old notion, that the more rings and the deeper the stuffing box the better the packing, should be discarded as entirely wrong. If the packing manufacturer were consulted at the time engines were designed, it would often be possible on the ordinary marine engine to lower the cylinders from six to eight inches, and keep the other proportions of the engine exactly the same. From this can be readily seen the importance of this subject. Think of the weight of metal saved in six inches of housings, piston rods, valve stems, etc.

INCREASE IN PISTON SPEEDS AND CYLINDER PRESSURES NECESSITATES HIGH-GRADE METALLIC PACKINGS.

Until late years, and at the time when steam pressures were low and piston speeds moderate, almost any kind of packing would give fair success, as on account of these low piston speeds and steam pressures the crossheads and guides would run very close, and pistons would usually fit cylinders much closer than would be possible under modern conditions.

It will frequently be noticed that many of the old types of packing which met with first-class success until a few years ago are giving much trouble on the more modern types of engines, with their increased piston speed and steam pressure, not only wearing out more rapidly, but causing heating of rods, which is a proof of excessive friction.

Many new engines have been seriously injured on account of this improper design of packing. With packing of proper design it has been found that metals may be

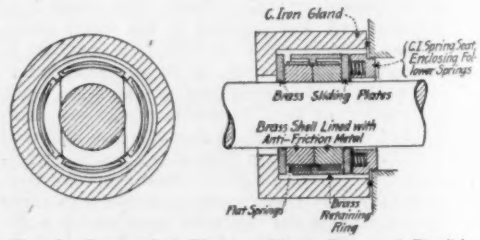

Fig. 2. Segmental Ring or Block Form of Flexible Packing.

used for packing rings which melt at a temperature within 50° F. of the temperature of steam in the cylinder. This is direct evidence of the small amount of friction.

IMPORTANCE OF CARE IN DESIGN, MANUFACTURE AND INSTALLATION.

To go into this matter fully would require quite a long paper. To get an idea of how much thought and care is required to design the last-mentioned type of packing it should be borne in mind that the amount of curvature of ball joints bears quite an important relation to the wear of rings for different kinds of service. Also, as previously explained, the shape of the interior of cup and white-metal rings should vary to a certain extent with the steam pressure, and again the quality of metal used for the wearing rings requires deep study to meet the varying conditions. An instance of this can be seen in railroad service, where for years it was thought that nothing but

a very expensive, high-grade babbitt metal would do for packing rings. After considerable experimental work had been done it was found that a metal costing one-quarter as much would not only prove more economical, so far as price was concerned, but would give much better service in the packing.

As superheated steam is slowly coming into use, the packing manufacturer must also follow and be able to take care of this question, and this requires a renewed study of the case and much experiment.

In practice, for most stationary and marine engine work, double packing is used, as shown by Fig. 4; that is, practically two stuffing boxes, the packing nearest the cylinder doing all, or nearly all, of the real work. The lower packing does little or no work until the upper packing is worn out or fails or leaks, when the lower packing catches this leakage or takes up the work in case of failure.

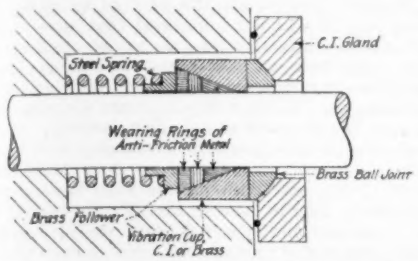

Fig. 3. Conical Ring Form of Flexible Packing.

CAREFUL ATTENTION NECESSARY FOR EFFICIENT MAINTENANCE.

Regarding the care and maintenance of this class, we quote from instructions given by one of the well-known packing companies:

The principle of this packing is a cone cup (known as vibrating cup) around rod or stem, into which are fitted the soft-metal rings. The soft-metal rings are held in vibrating cup by a spring, and the steam pressure forces them to make a tight fit around rod when engine is working.

The principle of operation of this packing is that the soft metals, after joints come together, are forced by spring and steam pressure into the vibrating cup; hence to the rod by a flow of the metal itself.

The soft-packing metal rings which come in contact with the rod, and which do the actual work of packing, are cut in halves with a small open space between them when first applied, so that they may rapidly conform to the surface of the rod. When they have done this the open space between these rings will be closed up, ends coming solidly together, and in this condition rings are intended to wear, and will last four or five times longer than they would if continually cut so as to stand apart.

One-sixteenth of an inch is all the space required between the ends of the packing rings when they are applied.

If rings are continually cut apart at joints the wear on the rods will be large, and rings themselves will have an extreme tendency to force out between the opening of the vibrating cup and rod. If these rings do not work properly when thus applied, and packings blow, there is something wrong, either with the mixture of the metal rings, the manufacture of the same, or the rod is taper or badly shouldered.

In applying new rings, or investigating trouble with packing, see that joints of rings are "broken." Examine faces of ball joint and vibrating cup and see that they are clean. Often packing will leak, due to foreign matter between ground faces of gland, ball joint or vibrating cup. Vibrating cups should fit within 1-64-in. of rods or stems. This will also prevent packing rings from being forced out between vibrating cup and rod, and will insure greater service of the rings. If absolutely necessary, soft packing may be used in the vibrating cups until rings are obtained, although it is far better to have spare sets of rings always on hand.

With double packings oil may be introduced into the lower stuffing box by means of a force pump. This oil when forced into the gland will entirely surround the rod, and the rod will then be running in a bath of oil. Should any leakage of water occur, it may be drained off and a litle more oil introduced. By this means of lubrication swabbing of rods may be entirely dispensed with and a large amount of oil saved. In applying this method of lubrication it is well to be careful regarding low-pressure rods when working in connection with the condenser, in order to prevent oil from being drawn up through the packing into the cylinder.

In connection with low-pressure cylinders it should also be noted, in packings of the conical-ring type, that it is necessary to make the springs in this case sufficiently strong to counteract the tendency of the air to unseat the packings and enter the cylinder. This is the only case in which springs bear an important relation to packings of this type.

CO-OPERATION OF MANUFACTURER AND USER ESSENTIAL TO DEVELOPMENT.

The packing manufacturer, in addition to his usual troubles, is often handicapped because he does not hear enough of the success or failure of his goods. If engineers assisted the packing manufacturer in this matter, stating the causes of trouble when it occurs, and working together with him in this way, I feel that much better results could be obtained than is the case at the present time. With multiple cylinders, high pressures and high piston speeds, this comparatively small part of the steam plant is growing rapidly in importance, and, although almost every engineer of note up to the present generation has patented, at some time in his life, a form of metallic packing, still hardly any of these are in use. There have been thousands of packings invented, but at the present time there are less than twenty-five recognized packings in the market.

INJURIOUS EFFECT OF WATER ON PACKINGS.

One of the greatest enemies and causes of trouble to any first-class packing is water in cylinders, which, when it occurs, demoralizes the packing. Strange to say, no metallic packing has been designed which will give first-class results as a water packing—the water rods of pumps, for instance. When first applied they usually work with fair success, but soon commence to leak and continue doing so. Also no thoroughly satisfactory packing has been invented and used for expansion joints. There is quite a large field for investigation in this direction.

THIRD-RAIL ELECTRIC TRACTION has been adopted by the Northeastern Ry., of England, for about 40 miles of its local lines around Newcastle. This includes several distinct divisions and branches, serving suburban districts, seaside resorts, manufacturing districts, etc. The lines have one, two and four tracks, and there are numerous junctions, crossovers, switches, etc., along the lines. Passenger traffic only will be operated by electricity, except on the Quayside Branch, ¾-mile long, where heavy grades and a badly ventilated tunnel make the use of steam engines unsatisfactory. The track is laid with 90-lb. rails of the bullhead section in cast-iron chairs, but the conductor will be an 80-lb. T-rail, on insulators of "reconstructed granite." The center of this rail is 19¼ ins. from the gage side of the track rail, and its head is 10¾ ins. above the ties, or 3¼ ins. above the head of the track rail. Ordinarily, the third rail will be between the tracks, but it will be on the outside where necessary, and all motor cars will therefore have contact shoes on both sides of each truck. At stations and other special points the third-rail will be protected by creosoted planks bolted through distance pieces fitted against the web of the rail. All the rails will be drilled so that the planks can be applied wherever required. The track rails will form the return circuit for the present, although a special return rail may later be laid between the track rails. Special splice bars have been designed, concave in section, to allow the rail bonds to be laid between the rail and splice bars, two bonds on each side. A direct current of 600 volts will be supplied to the conductor from five substations, containing 14 rotary converters of 800 KW., or about 15,000 HP. in all. These converters are designed to work at 100% overload for ten minutes without serious sparking, and to withstand a momentary overload of 200%. Current will be supplied from the new power station of the Newcastle Electric Supply Co., which station is equipped with turbine generator units of 3,500 KW., capable of delivering 5,000 KW. for two hours. The alternators will be of the rotating-field type, with direct-connected exciters, and will generate three-phase current at a pressure of 6,000 volts. There will be both motor and trail cars, all carried on trucks, and each motor car will have two 150-HP. motors mounted on one truck. The multiple-unit system of control will be adopted, and the unit train will consist of two motor cars with a trail car between. The first car will have a baggage compartment and seats for 48 first-class passengers. The middle car will seat 70 second-class passengers and the rear car 68 third-class passengers. The cars are 55 ft. long over the sills. The trucks have 36-in. wheels and 7-ft. wheelbase, and the total wheelbase is 47 ft. For freight service on the Quayside Branch there will be two 50-ton electric locomotives, each capable of starting a train load of 150 tons on a grade of 3.7%, and hauling this train up the grade at 10 miles an hour. The passenger trains will have an average speed of 22 miles an hour including stops, but through trains will have a higher average. The work is being done under the direction of Mr. Charles Harrison, Chief Engineer, and Mr. Wilson Worsdell, Mechanical Engineer, of the Northeastern Ry. The electrical equipment of the substations will be supplied by the Westinghouse Electric & Mfg. Co., and that of the cars by the General Electric Co.

THE INDUSTRIAL SCHOOLS OF GERMANY are reported upon by E. L. Harris, U. S. Commercial Agent at Eibenstock, Germany, in Consular Reports for July 23, 1903. In Saxony alone there are 287 schools of this class divided into five divisions, ranging from a primary school to the advanced school. A type of the latter class is that at Chemnitz; this school covers five distinct minor schools, known as the industrial academy, architecture, machine construction, dyeing and industrial drawing. The first furnishes four courses—for mechanics, chemists, architects and electricians. The special industrial schools—of which there are 150 in Saxony—instruct pupils in 28 different trades and industries, and at least 28 hours per week is devoted to practical work by each student. In Saxony, there are 32 industrial schools for drawing and painting, 21 schools for women, girls and children, and 44 industrial primary schools which give to those completing the public school course a chance to prepare themselves in a general way for some trade or industry. Other German States are doing the same work, though the figures are not given except in a very general way. Hessen, for example, boasts that there is not a single village, however small, which has not an industrial school of some kind, all under the direction of the Minister of the Interior.

IMPULSE WATER WHEELS UNDER HIGH HEAD have been put into use recently at Redlands, Cal., where a water-power plant generates electric current for the Edison Electric Co. of Los Angeles, Cal. The effective head of water used is 1,912 ft.; the question arose whether this head should be utilized directly or in several stages, the single-stage plan being finally decided on. The plant is divided into units of 750 KW., running at 430 r. p. m. and capable of standing an overload of 25%. Three of the wheels were furnished by the Abner Doble Co., of San Francisco, and one by the Pelton Water Wheel Co. of the same place. The generators, 14-pole machines for 750 volts, are from the General Electric Co. of Schenectady, N. Y. We are informed by the Abner Doble Co. that they furnished one wheel on a first order, and that the results of tests on this wheel in competition with the Pelton wheel gave them the contract for the other two wheels. The tests showed that from half load to 25% overload the Doble wheel operated with an efficiency of 80 to 84%. The high efficiency on part load is said to be due in large part to the use of a regulating nozzle of the needle type. The diameter of the wheel is 7 ft. 8 ins. It is supplied by a single nozzle giving a 2-in stream.

PIG IRON PRODUCTION IN GREAT BRITAIN in 1902 was 8,517,693 tons. The home-consumed pig iron was distributed as follows, according to the statistical report of the British Iron Trade Association:

	Tons.
Ship building	1,200,000
General merchant iron and steel	1,108,000
General foundry purposes	1,000,000
Machinery for home trade	700,000
Tin plates used in home market	220,000
Railway material	450,000
Tools, hardware, implements, etc	450,000
Naval and military purposes, etc	200,000
Total	5,328,000

THE TRAFFIC OF THE SUEZ CANAL for the year 1902 was considerably greater than for either 1900 or 1901. The number and tonnage of the vessels passing through the canal during each of these three years were as follows:

Year.	No. of vessels.	Tonnage.
1900	3,441	9,738,152
1901	3,699	10,823,840
1902	3,708	11,248,413

THE REGULATION OF AUTOMOBILES is now being taken up in Great Britain, and amendments for this purpose are proposed for the existing laws relating to the use of traction engines and steam rollers on public highways. Under the law of 1896, the Local Government Board was authorized to fix the maximum speed at not more than 14 miles an hour, and the Board set the limit at 12 miles an hour. As it is unreasonable to set the same limit for city streets and country roads, it is now proposed to abolish this legal limit and to allow local boards to make speed rules suitable to their localities. There would be a general rule forbidding the driving of motor cars "recklessly or at a speed dangerous to the public," but there will be much trouble in deciding as to what constitutes recklessness and what speed is actually dangerous to the public. Under the proposed law a driver may be punished for reckless driving or excessive speed whether or not his action imperilled any one on the road. This will act as a check to prevent "scorching" when the road appears to be clear. Each machine must be registered and display its number, and every motorman (professional or amateur) must pass an examination and secure a license. The refusal of a motorman to give his name in case of arrest, or the giving of a fictitious name, will be considered as an additional violation of the law equal in gravity to the violation with which he is first charged. The maximum penalty will be a fine of $100 or imprisonment for three months for a first offence. For a second offence, the maximum is $250 or six months' imprisonment.

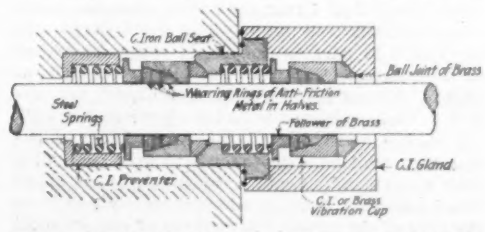

Fig. 4. Double Packing for Stationary and Marine Engine Work.

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXIV-XXIX. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

In another part of this issue appears the report of a commission of eminent engineers on the condition of the walls of the Jerome Park Reservoir, now under construction. The report is divided into two parts, the first part being a discussion of the water-tightness of the retaining walls, and the best methods of securing a water-tight bottom of concrete; while the second part is a discussion of the use of stone dust from the crusher in place of sand for mortar.

The original specifications called for sand, and when it was found that the rubble retaining walls were not absolutely water-tight, the leakage was attributed in part to the use of stone screenings in the mortar. This was but one of the several absurd charges made by the Merchants' Association in their endeavor to find a nigger in the wall.

Trenches were dug in the earth back of the retaining wall to a depth of 3 to 6 ft. and filled with water; and, of course, the water found many small passages, through which it slowly leaked to the face of the rubble. A member of our editorial staff visited the reservoir while these tests were in progress, and was surprised to know that any engineer would expect a thin rubble wall, laid in "dry mortar," to be perfectly water-tight. As might have been predicted, the leakage was greatest near the top of the wall, where single stones extend from face to back, while the worst leaks were through the horizontal joint between the cut-stone coping and the top of the rubble.

Any engineer who has even for a few minutes watched the work of masons in building rubble will know that a tight joint where "dry mortar" is used is the exception rather than the rule. To have reasoned that, because the rubble leaked, the mortar must be poor was assuredly the height of absurdity.

Assuming that in some mysterious way the stone dust were inferior to sand as a mortar-making element, is it not apparent that in such a case we should find a general oozing through of water all over the face of the wall, rather than a concentration of water in a few joints? What effect could stone dust have in enabling water to find its way through the horizontal joint under the coping, and not through some thicker joint a few inches lower down?

The tests of tensile strength of the stone-dust mortar, given in the report, show how absurd were the claims that it was an inferior and "leaky" kind of stuff.

The Commission states in the report that the rubble of the character specified and laid at Jerome Park cannot be expected to be absolutely water-tight, and in that statement we fully concur. But the Commission rather weakens its argument by adding that the wall had not been finally pointed where the leaks were worst. If one can ever speak of "pointing" a rubble face having mortar joints several inches thick, then surely this rubble had been pointed in the very act of making it, and any further pointing would be mere plastering.

As to the amount of leakage through the rubble, it was too insignificant to cause excitement in the minds of any but the very ignorant or the hypercritical. The earth back of the wall would readily dam back and hold the water alone, so that the wall really serves only to prevent any possible destruction of the earth embankment by wash or by erosion.

The Commission recommends the use of expanded metal in the concrete floor where bedrock adjoins earth, and it recommends the building of small levees to keep the concrete floor flooded with water after laying. These and other recommendations make the report interesting and instructive reading.

In conclusion it may be noted that all well-meaning municipal reform organizations may note with profit the experience of the Merchants' Association of New York city in its recent campaign against the Croton Aqueduct Commission in the matter of the Jerome Park Reservoir. Having acted a most creditable part in downing the proposed Ramapo water supply scheme, a few years ago, the Merchants' Association recently entered upon a campaign against the Aqueduct Commission. What we particularly desire to point out is the apparent failure of the Merchants' Association, and of public-spirited organizations elsewhere, to grasp the technical features of some of the problems they have attacked. Zealous assistants, apparently with no technical training whatever, have conducted more or less exhaustive investigations and discovered dangers which were founded on misconceptions. Technical advice, when sought, has been too long deferred, and has not always been founded on more than superficial investigations of the questions at issue. It is well that bodies like the Merchants' Association are turning their attention to municipal problems. The good they can do through watchfulness is great, but they cannot exercise too much care in selecting men and methods to carry on their work.

The renewal of the proposition for general subways, or pipe galleries, along the lines of extensions to the New York underground rapid transit railway system deserves the support of all branches of the city administration, the press, and the public generally. The reasons for pipe galleries in large cities have been presented repeatedly in these columns. They include economy in street pavement repairs and better pavements generally; diminished leakage of both gas and water; greater ease and cheapness of repairs to water and gas mains; and a vast decrease in the interruption to street traffic and the interference with the business of adjoining property-owners and their tenants.

WHY PAVE RESIDENCE STREETS FROM CURB TO CURB?

While there is a seeming tautology in the phrase, macadam roads for residence streets, it is apparent, we think, that a road can exist in a street, and that the two terms are not synonymous. A street embraces all the area between property lines bounding the highway of a village or a city. A road is commonly taken to mean that portion of any highway traveled by vehicles. The term street may be narrowed to include only that portion of the highway between curb lines, while the term road may be narrowed to include only the paved portion of the traveled wheelway. Obviously we may have a macadam road within a street, and it is of such roads that we shall speak.

Somehow, we know not how, it early became the custom to pave streets from curb to curb. Possibly this practice grew out of the necessity of paving business streets from curb to curb, and as business streets are the first to be paved in every city, it was not unnatural that when later the residence streets were also paved, similar designs prevailed. So fast-rooted is the idea that all of the street must be paved, that where a macadam road enters a city we often see a sudden increase in the width of metalled roadway. Thus on several of the streets in Rochester, N. Y., one finds a width of macadam more than double the width of the macadam on the road beyond the city limits. And in looking through the reports of city engineers one is struck with the persistence of this practice of paving from curb to curb where paving is used at all. Now what is the justification for the expenditure of money involved in paving residence streets their full width? Rarely is there a residence street where traffic is great enough to justify a paved trackway greater than 16 or 18 ft. in width, and if the passing vehicles on any residence street are watched it is seen that they cling closely to the center. One may argue till the crack of doom to convince the public that it is poor pavement economy to always travel in one narrow path, and one may placard a road from end to end with signs, begging, warning, threatening—yet will horse and man cling to the center of the road. The horse finds it easier traveling there for all feet are on a level, and the driver finds it pleasanter riding where the seat is level, too; so animal and human comfort take precedence over pavement economics.

Since then the center of a street receives practically all the travel what reasons can be given for paving areas seldom pressed by hoof or wheel? It has been argued that carriages and delivery wagons stopping in front of houses make necessary a pavement up to the curb. Let us see what there is in this argument. An earth road is usually very bad only during the wet season of the year, and then its badness varies directly with the amount of traffic that it must bear. It is not the occasional passing of a wheel over an earth road that cuts it into ruts, but the repeated passage of many wheels which churn the water and the earth together, until deep ruts are formed ready to receive the very next fall of rain and store it there. Even on country roads paved with 12 to 16 ft. of macadam there are many residences where wagons and buggies turn out to stop, yet we seldom see a mud wallow in consequence. And as one looks with critical eye at the earth flanks of narrow macadam roads in village streets the same absence of mud ruts is noticeable. Macadam roads are giving the greatest satisfaction in many a village even now, and the wonder is that in view of such object lessons, residents of unpaved city streets still fancy that they must have a pavement from curb to curb or none at all. Thus in that Utah city of magnificent distances, near Great Salt Lake, miles upon miles of streets lie unpaved, although mountains of rock are close at hand. So it is in many places. The very spaciousness of the streets acts to prevent all paving.

Not only is the matter of supposed necessary width a deterrent, but the necessary thickness of the macadam is usually overestimated. In spite of the fact that abundant experience has shown that macadam 6 ins. thick will uphold the heaviest of loads on all but the softest of clay soils, still we find a foot of macadam adopted as the standard for residence streets. Often it is asserted with the utmost gravity that while 6 ins. of macadam may serve on country roads, it will never do at all on city streets, and there the argument ends—in mere assertion.

When in doubt as to the proper thickness of macadam it is hardly good economics to make assurance doubly sure by using a factor of safety of two or more. At worst the failure of the macadam through excessive thinness is a failure easily remedied, for, in the words of that genius who recommended using tin oil cans to raise the Maine, "If 100 of them will not raise the wreck, why simply apply more cans."

LETTERS TO THE EDITOR.

Riveted Joints Under Eccentric Loading.

Sir: In reply to your invitation to discuss the question of riveted joints under eccentric loading, I would say that I think that Mr. John L. Hall's exception, as to the unequal distribution of shearing stress, is not well taken. In the great majority of riveted joints dealt with in bridge work the form of the joint is that of a plate girder (usually double) and, as is well known, the shears, both vertical and horizontal, are with all needful accuracy assumed to be equally distributed over the web. It is only in solid rectangular sections that the unequal distribution of the shears over the section of the beam plays an important part, and cases of joints under eccentric loads where this distribution would come into play are, I take it, rare. Mr. Hall's expression that the distribution of stresses in beams is considered an "economical law" seems to me to be awkward. It is a matter in which we human beings have little choice. It is a law of nature and governs all beams whether designed economically or not.

As far as the writer knows, practically no attempt has heretofore been made in bridge or structural work to calculate stresses on rivets in such joints. If the matter has been considered at all a rough guess has sufficed. The one exception I know of is Mr. H. S. Prichard, who some years ago made up tables of standard beam connections in which this action was taken into account. It seems very difficult, however, to overcome the moment of inertia of the American engineering profession and little good seems to have come of that attempt. How far the present one will succeed remains to be seen.

In conclusion I would say that all engineers will agree heartily with the editor's injunction, "Don't build them." It is sound common sense, as is shown by its being in accord with the hoary proverb of that practical hard-headed race, the Chinese: "If you do not wish anybody to know that you have done a thing, don't do it."

Yours truly, Henry Szlapka,
Consulting Engineer.

Narberth, Montgomery Co., Pa., July 27, 1903.

Steel Dams for Storage Reservoirs.

Sir: The letter in the Engineering News of June 11, by the undersigned, has been followed by discussions bearing on the subject of dam construction; by the Editor on June 11, by Mr. Burr Bassell on July 2, and by Mr. H. M. Wilson on July 16. I offer the following comments, point for point

(1) In storage works, where the economy of water is of foremost importance, as for instance in the irrigation districts of the United States, deep reservoirs are in most all cases cheaper in construction than shallow ones of the same capacity and are, at equal cost, by far preferable on account of the diminished evaporation loss. Cost and conditions under which a reservoir of two or three hundred feet depth can be easily constructed would therefore seem worth the while to ascertain.

(2) Theoretical investigations and practical experience point to the fact, that masonry dams cannot be safely and economically constructed for greater water pressure than about 100 to 150 ft. Of the several dams under construction and with greater height none has stood its test, so far.

(3) Simple rock-fill dams and earth dams are more reliable for great height at times when water should accidentally rush over the crest. The dam prepared by Mr. Bassell could hardly stand the wear and would be carried away by water pressure of say 200 ft. if an appreciable hole in the upstream cover should occur. The type suggested by Mr. Wilson could certainly be improved by my former suggestion for low dams, protecting the steel plate against rust by plastic clay puddle instead of concrete. Both plans would result in more ephemeral structures than the steel dam proposed. As the steel-concrete structure is acknowledged to be pliable in consequence of the deformations resulting from pressure and thermal changes, it will admit water to the metal, but no painter nor inspector.

(4) High dams call for water-tight sheeting, which we have in the shape of steel plates, sufficient for all cases, and they call for the cheapest structure to support the same, which we have in the steel column. All metal in contact with water should at times be readily accessible for inspection and maintenance. If it can be shown that a column of a certain class carries with safety a greater load than another for one dollar and has equal durability, this column should have the preference, and if a very great amount of such material can be advantageously employed, it is certainly worth the while to test it.

(5) To combine the best public interest with fairness against all bidders on dam structures it would seem desirable that such bidders should have preference who will guarantee the capacity of their structures under test-load.

(6) No trouble is anticipated in a steel dam with an occasional rush of almost pure water over the same, falling down on a solid bank of rock. The erosion alluded to by Mr. Bassell as Niagara effect would call for a thousand years of work with an endless supply of mighty and hard grindstones. Very respectfully,

Charles R. Steiner.

225 14th St., Denver, Colo.

Relative Strength of Wet and Dry Concrete.

Sir: In your issue of July 16, under the heading "The Relative Strength of Wet and Dry Concrete," the table of tests presents some apparent discrepancies sufficiently remarkable to deserve attention.

(1) The averages of three tests each of medium wet concrete lightly tamped are identical for seven and 30 days respectively. Moreover the three tests, Nos. 4, 5, 6, at seven days are identical with Nos. 19, 21, 20 at 30 days.

(2) The average of the same mixture and tamping is weaker at 90 days than at seven and 30 days.

(3) Medium wet concrete tamped hard is weaker than the same lightly tamped at seven days.

(4) There is less than 1% increase in strength from 30 to 90 days in medium wet concrete hard tamped.

Discrepancies 2 and 4 are remarkable in view of the large increase in strength shown by both the dry and wet mixtures for the same period. Assuming that the samples were prepared under proper conditions and that the results as given are accurate, it would appear that concrete mixed with the proportion of water used in the preparation of the cubes of "Medium" wetness is not reliable.

In the January issue of "Municipal Engineering" is given a table of results of over 1,000 tests of concrete which is well worth consideration. In the same issue on page 32 is a summary of several hundred tests made for the State of New York by Geo. W. Rafter on 12-in. cubes of limestone concrete, using five different brands of Portland cement, one being a silica Portland. The following is quoted from the "Municipal Engineer":

> The blocks made to represent "dry" concrete were, generally speaking, only a little more moist than damp earth. Such blocks require a large amount of ramming in order to flush the water to the surface. In the "plastic" blocks the mortar was made of ordinary consistency used by the average mason. A moderate amount of ramming brought the water to the surface in these blocks. In the "excess" blocks the water was so far in excess that the concrete quaked like liver under moderate ramming.
>
> The proportion of cement to sand was 1 to 2 and 1 to 3, the results being the means of equal numbers of these two qualities of mortar. The proportions of mortar to stone were 33% to 40%, very nearly equal numbers of blocks of each proportion being used.
>
> The resulting average compressive strength of 156 blocks of "dry" concrete was 2,470 lbs. per sq. in., of 144 blocks of "plastic" concrete 2,294 lbs., and of 148 blocks of excess concrete was 2,180 lbs. Nearly all individual results show a similar range of values, which is sufficiently pronounced to warrant a definite statement in accordance with the figures given.
>
> The age of the blocks when tested was more than 18 months and less than 24 months. The crushing test tests were made at the United States Arsenal at Watertown, Mass. Mr. Rafter emphasized the fact that the dry concrete blocks must be sprinkled or kept moist until fully hardened in order to develop their full strength.

While reports of tests are always interesting, the writer believes that they should be accompanied by the fullest information about all ingredients, proportions and conditions, more especially when they apparently negative previous data. Very truly,

E. R. Frink.

Baltimore, Md., July 18, 1903.

The Testing of Bitumen for Paving Purposes.

Sir: I desire to make a few comments on your report of the discussion on my paper, "Testing Bitumens for Paving Purposes," in your issue of July 9, and also on the letter of Mr. Richardson relating to this subject in the following issue. In your comments on the proceedings of the American Society for Testing Materials you mention that I read the above paper, and give an abstract of the methods employed for determining the relative action of water on different asphalt cements. Please allow me to correct a statement in the description of the second method for testing the action of water. You say "Another method is to make two cubes of the cement, etc." This should read, "Another method is to make two cubes of the paving mixture, etc."

You then proceed to give an abstract of a portion of Mr. Richardson's comments on the paper; one of these was that Mr. Richardson severely criticised the Washington authorities for using a 1, 4 and 10 concrete base for asphalt, as water would work up through such a concrete and ruin the pavement. This statement of Mr. Richardson's I denied, saying that there had never been a pavement on this class of concrete, that showed any action of water, as this concrete had only been in use two years. The pavements that are rotting from water are on 1, 2 and 5 concretes, and not alone in Washington, but in every city that I have ever visited.

I would like to say further that we have pavements rotting here on a concrete as rich as 1, 2 and 4, and in another case on concrete 8 ins. thick, made 1, 2 and 4½, the upper surface troweled over with a mortar so as to get a finish somewhat like a sidewalk. We have tried underdraining the concrete of pavements to prevent water working up through them, but find it not entirely satisfactory. There is one case which I have in mind where the pavement rotted at the end of two years. After putting in a good concrete and underdraining it, the pavement went five years in fairly good condition.

As to Mr. Richardson's letter in your issue of July 16, I agree with Mr. Richardson in that all asphalt surface mixtures are attacked by water in the course of time, but I go further and say that mixtures made from some asphalts are very much more rapidly disintegrated than those made from others. I also agree with him that the grading of the sand in the mixtures has some little effect in preventing the entering of water into the mixture, but the best graded paving mixtures made with some asphalts rot very much more rapidly than poorly graded mixtures made with other asphalts.

I wish to take exception to what Mr. Richardson says in his letter about the important fact that you failed to mention in your issue of the 9th inst., that is, "that the experts from the road material laboratory of the U. S. Dept. of Agriculture do not agree with the statement of Mr. Dow as to the cause of the action of water on asphalt surface mixtures." Mr. Logan Waller Page, Chief of that laboratory, called my attention to this statement in Mr. Richardson's letter, and said that he did not make any statement disagreeing with what I said on the action of water on asphalt. Mr. Allerton Cushman, chemist of that laboratory, merely made the statement, based nearly entirely on theoretical reasoning, that he coudd not see how the action of water on Trinidad asphalt could be attributed to the presence of 0.3% of soluble matter. Mr. Cushman's remarks really had nothing to do with the discussion of the paper, as I say nothing at all about the cause of the action of water on asphalt, but merely say in the paper that an asphalt should be examined to determine whether or not it is attacked by water or moist air.

I hope that you will see fit to publish this letter, as the subject is of more than passing interest, and is one that should be investigated by engineers and chemists.

Yours very truly, A. W. Dow.

Washington, D. C., July 30, 1903.

The Proper Age of Test Pieces for Accelerated Cement Tests.

Sir: I have just read with great interest your editorial headed "Notes on Recent Cement Tests," and find on page 101 in a summary of the obstacles to the general use of accelerated tests, referred to in Mr. Taylor's paper, a most intelligent and clear conclusion as to the best method to make these tests. In discussing Mr. Taylor's paper at the meeting of the American Society for Testing Materials, at the Delaware Water Gap, I advanced a theory on this subject and recommended briefly that the proper time for making the accelerated tests should be at the expiration of the 7 day or 28 day periods for the tensile or compression tests. I have gone into this a little more fully than I am now writing you and will send you a copy of my discussion of Mr. Taylor's paper, and I trust you will find a way to give it day-light in your very valuable paper.

Yours truly, American Cement Company,
R. W. Lesley, President.

Philadelphia, Pa., July 31, 1903.

(The portion of Mr. Lesley's discussion which refers specifically to the proper age of test pieces for accelerated cement tests is given in the following paragraphs.—Ed.)

The most important thing shown by Mr. Taylor, in his very valuable paper, is that boiling means seasoning, and his figures on the cement boiled after holding them for a period, as shown in Table I., prove conclusively this fact, and throw us back to the old practice which was used by the English engineers many years ago, and is referred to in an interesting paper on the Vernwy Dam, read before the British Institute of Civil Engineers some years ago.

These figures of Mr. Taylor's are corroborated by experiments at our own works in our own laboratory, and also by the testing experts of the New York Rapid Transit Commission, who are testing our cement at our works. They demonstrate very clearly that as a matter of practice, the right time to make the accelerated tests of a cement is not at the beginning of the testing operation when the briquettes are made, but at the conclusion. In other words, if the practice in the testing of cement on public works is only to accept cement after 28 days' test, and not to allow it to be used until after that test is passed, it certainly appears clear that the time to make the accelerated tests, which takes at the most 24 hours to conclude, is when the final test briquettes are broken, and not at the beginning of the operation.

The cement which is to stand the accelerated test is the cement which is delivered on the work and which is ready for use, not the cement which is hot from the millstones, or just made and submitted immediately after manufacture to the testing laboratory for mechanical tests only.

Certainly if experience shows that this test really is a measure only of the seasoning of cement, it would be better to make it at the end of the mechanical tests, because at that time the cement would have aged and will more resemble the condition in which it is to be used, and the boiling test will give a better indication of its true value.

It can be readily understood that for the purpose of the making of the 7 day and 28 day tests, and for the purpose of testing fineness and specific gravity, the manufacturer submits the cement promptly after manufacture, and the consumer receives it as in the condition then ex-

isting. The cement which is received is tested for tensile strength and the other requirements; having passed these requirements and being in a condition to be delivered and accepted on the work at the expiration of either the 7 day or 28 day periods, the time is then reached to determine its condition so far as expansion and contraction is concerned.

In view of the particular doubt that seems to exist in the minds of all engineers, as indicated by Mr. Taylor's paper, and as indicated in the report of the Board of United States Army Engineers, Professional Papers No. 28, Washington, D. C., and as pointed out in the report of the American Society of Civil Engineers, Progress Report of Special Committee on Uniform Tests of Cement, Jan. 21, 1903, as to the absolute reliability and efficacy of boiling, hot water and other accelerated tests, it would seem that this method of making the accelerated tests at the expiration of the tensile and other tests at the time of the delivery of the cement on the work, would be the proper way, and would overcome many of the objections now urged against this test, which, to my mind, is at the most a doubtful and uncertain expedient.

These conclusions above referred to are as follows:

The Board of Engineer Officers, Professional Papers No. 28, Washington, D. C., 1901, says, under the head of "Accelerated Tests":

This test is proposed as suggestive or discriminative only. Except for works of unusual importance it is not recommended that a cement passing the other tests proposed shall be rejected on the boiling test.

The American Society of Civil Engineers, Progress Report of the Special Committee on Uniform Test of Cement, Jan. 21, 1903, state, under the head of Constancy of Volume, says:

In the present state of our knowledge it cannot be said that cement should necessarily be condemned simply for failure to pass the accelerated tests; nor can a cement be considered entirely satisfactory, simply because it has passed these tests.

The whole question of the soundness test is one that is particularly worthy of consideration and investigation from the fact that we are in this country, the pioneers in the use of rotary kilns, and the general literature hitherto upon this subject has been literature based upon the product of the dome kilns used in Europe, and it is just such work that Mr. Taylor is doing that will enable us to determine whether the accelerated tests applicable to dome kiln products are safe to be used with rotary kiln products, or whether they will have to be modified in order to be a true criterion for the product of the rotary kiln.

Farther Remarks on the Aesthetics of the Manhattan Bridge and Engineering Impressionism.

Sir: In view of your remarks appended to my letter published in your issue of July 23, may I add a few words? It is unfortunately true, that, as you remark, the Art Commission has given its approval to the new bridge plans. It may also be true that Mr. Lindenthal has duly considered the aesthetic element in his new plans. But the Art Commission were not called on (so far as I know) to express their preference between the former and the present design; nor was Mr. Lindenthal able, with his best efforts, to make a chain bridge anything but a chain bridge. I think no one can compare the new plans with the two existing bridges and not say the Manhattan Bridge is the ugliest of the three, just as the chain bridge over the Allegheny River at Pittsburg is the ugliest of the three.

The reason for this inherent architectural defect is not far to seek, it is top-heaviness, which, wherever applied, invariably produces the same effect to the eye. The vertical stiffening trusses, heretofore a feature of the floor or roadway, are now raised to a level with the cables, which not only raises them higher up, but also makes them more conspicuous—in fact, makes the cables the biggest feature of the whole bridge—and thus doubly aggravates the defect mentioned. But, in addition to this, the towers, or what would, in other bridges, be called piers, are reduced in the proposed new bridge to mere stilts (in profile, at least), this being apparently made necessary by the rigid attachment of the chains and trusses thereto (also apparently an inherent feature of this design) instead of merely resting thereon as in the true suspension bridge. The result is exactly to reverse the relative proportions between the towers and superstructure of the beautiful Brooklyn bridge, and to give the new bridge a semi-ludicrous aspect similar to that of "bug" light-houses and like stilted structures. It is submitted that no amount of filigree work or decoration —be it "Roman," "Gothic," "Renaissance," or other—can alter this fact.

Although I have not the Mayor's letter of appointment before me, it appears from the report itself that it contained four specific inquiries, the answers to which are summed up at the end of the report. The first of these evidently related to the superiority of the new plans over a cable suspension bridge. It seems to me that this is equivalent to a call for a decision of the question chains vs. cables, which itself implies an investigation and reasons based on solid facts and not on mere engineering judgment or opinion, however experienced. Yet to this first and most important question the Board devoted but one subordinate paragraph of their report; in that paragraph only two sentences refer to the relative merits of chains and cables; and those two sentences are mere unproven, unsupported statements, every one of which has been since contested by other engineers. Therefore we are as far from a solution of this question as we were before the Board was appointed.

As regards the actual merits of the question, it is admitted by the Board in their report that even when special steel is used, more than twice the weight of metal will be needed for chains than for cables; and it stands to reason that this special steel, worked up into a special form by a special plant, ought to cost as much per pound as wire such as is now in current use, or, in other words, that the chains would cost at least twice as much. But the Board states that "the cost of eye-bar chains and wire cables in this bridge would be about the same," and such a paradox evidently calls for some sort of explanation.

That engineers may be called on to give a "yes-or-no opinion" is doubtless true; but the report made by the Board shows that they did not so interpret their appointment, as they fully discussed the possibilities and design of the new bridge. Besides, is an engineer ever asked to abstain from giving reasons? Even if the opinions are for the benefit of laymen, it is rare that the reasons cannot be summed up in simple non-technical form, and unquestionable that it will better satisfy the client, as, even where the latter cannot fully appreciate them, it is evidence that the expert speaks from conviction, the grounds of which he is not afraid to expose to criticism. So are the opinions of the Attorney General given for the benefit of laymen; but they are invariably accompanied by reasons which are open to criticism by the profession, as they should be; and the same is eminently true of engineering opinions of public works involving millions of dollars expenditure. As the Mayor needed an engineering report to fortify his decision against criticism, so do the engineering board need facts and reasons to fortify theirs; for this thing is not done in a corner. The fact remains that the public is yet without adequate explanation for the preference given to the new bridge plans; it is admitted that the cost will exceed by several million dollars that of the old plans; can it be said that such explanation is uncalled for?

George W. Colles.

Montreal, Canada, July 27, 1903.

An Object-Lesson in the Volume of Water Required for Fire Protection in Crowded Mill Yards.

Sir: A recent factory fire at Lowell, Mass., affords a good object-lesson in the volume of water required for fire protection in crowded mill yards, and is of perhaps even greater value as again demonstrating that with an abundant water supply a conflagration does not get beyond control of intelligent management. The occupancy of these cotton factories is naturally much more hazardous than the ordinary city block and the areas tenfold larger than the building laws of our great cities would tolerate, yet by means of good engineering the fire loss and the insurance cost is kept down to marvelously small proportions. Less than 1-12 of 1% per annum has been the record of insurance cost for six years past.

The experience obtained, from time to time, by the Factory Mutual Insurance Companies, goes far to show that the advance of any conflagration can be checked, even among buildings of combustible occupancy and large areas, if an adequate water supply is intelligently directed.

The fire now referred to destroyed the boiler house of the Merrimack Mfg. Co., at Lowell, Mass., on the night of July 18, and threatened for a time to destroy surrounding buildings of value reaching into the millions. At no place in the United States are greater values in high factory buildings of large area concentrated than along some of the Lowell canals. The arrangements for fighting fire at these mills, were, for many years, under the general supervision of the late James B. Francis, past President of the American Society Civil Engineers, and as a result the water supply of the Lowell mills is unusually ample, and the private fire patrol is uncommonly good.

There are very few, if any, public fire supplies outside of those in some of the large cities like Boston or New York, which are designed so as to permit concentrating such large volumes of water on a single building as is possible at many of the factories where the layout of the fire protection is supervised by the engineers of the Factory Mutuals.

Tests made a few years ago by the engineers of the Factory Mutuals, in co-operation with those of the Locks & Canal Co., showed that more than 40 fire streams could be concentrated simultaneously on certain of the more important single buildings, from the elevated reservoirs, without the use of steam fire engines, and the organization of the private fire brigades or fire patrol service of these Lowell mills is along the line of having the watch service in two detachments, with comfortable lodgings inside the mill yard for the men off duty.

This watch is supplemented by a system of electric alarm bells at the near-by dwellings of many of the repair shop force, and a push button is placed at each room of the mill by which an alarm can be instantly sounded in the "watch room" and at the dwellings of the other members of the fire brigade. The ringing of this alarm at night brings a large corps of men to the scene of the fire in an almost incredibly short time, who are thoroughly familiar with the property and accustomed to the manipulation of the private fire apparatus.

The fire of July 18 broke out at 8 p. m.. It originated from spontaneous combustion in a small lot of soft coal of unknown antecedents, procured during the coal famine of last winter and now left at one end of a 5,000-ton pile of New River coal. This coal that had shown signs of heating was being shoveled over, when a slide occurred just as the pocket of fire was reached, sending up a cloud of dust which took fire and flashed through the coal pocket. This was of wooden construction and about 500 ft. in length, and adjoined a brick boiler house about 400 ft. in length which had a wooden roof. All this wood work of the coal pocket and the boiler house was, of course, thoroughly well seasoned, and the fire spread with great rapidity and burned with great fierceness. On the westerly side of the coal pocket, directly opposite to where the fire started, and only about 25 ft. distant, was the end of a cotton mill six stories high, as shown by the accompanying photograph, and adjacent to this was a steep roofed building containing the pickers and a large amount of opened cotton. Both of these neighboring buildings were without fire shutters and relied for their protection upon automatic sprinklers and the excellent private fire brigade.

VIEW OF RUINS OF FIRE AT THE MILLS OF THE MERRIMAC MFG. CO., LOWELL, MASS., ON JULY 18.

The watchman on duty saw the flames, rang the private fire alarm, and the first man from the outside entered the yard within four minutes and went immediately to the top of the six-story mill on the Tremont and Suffolk side. The watchmen on duty, assisted by the mill force, which rapidly arrived, laid hose streams in every story of this high mill; the automatic sprinklers opposite the windows promptly opened, and as the wood work of the window sash and casings were burned away by the intense heat, and as cinders and fire brands rose into the

air and were drifted in through these window openings by the moderate wind blowing at the time, the continuous action of the sprinklers adjacent to the windows, and the attention of the hose men at particular points overcame the shower of sparks and the fire gained no important headway, notwithstanding the large amount of very combustible cotton scattered through all these rooms. On the Merrimack side, after some momentary confusion, the private fire brigade was quickly aroused and at work, and the city department arrived and co-operated without friction soon after. The great advantage of this automatic sprinkler protection is its instant readiness without further human intervention. Where the heat becomes great there the sprinkler opens.

About 15 hose streams were in use simultaneously on the Lawrence side of the fire when at its height, and 25 hose streams on the Merrimack side.

The important lesson of this fire is the great value of automatic sprinklers in protecting against an exposure fire, and second, the advantage of supplementing the work of the sprinklers by the use of inside hose streams in the hands of an efficient fire organization familiar with the premises. In all about 10,000 gallons of water per minute were drawn while the fire was at its height.

In close proximity to the boiler house were various factory buildings and storehouses, containing contents of great value, and in none of these will the loss be a serious one, and in the boiler house itself, the non-conducting covering that had been applied to the up-takes, flues and piping served admirably for heat resisting insulation. The boiler plant was again in operation in five days. The total loss by fire damage and water damage at both factories will probably not exceed $100,000.

The slow yielding of heavy Georgia pine timbers to the hot fire is shown in the views of the boiler-house ruins.

This slow yielding of thick plank is continually being demonstrated in the investigation of the fires which occur in the more than 2,000 factories under the supervision of the Factory Mutual Inspection Department, and is the reason why this type of construction, known through New England as "mill construction" or "slow burning construction" is in distinction to joisted construction or "quick burning construction" and is so strongly advocated. It is found that a floor or roof of 3-in. plank, supported by 12 × 16-in. timbers and wooden posts, possesses far greater resistance to fire than a steel truss roof.

It is held by engineers familiar with this type of construction, and the fire record, that the cheapest and best "fireproof construction" yet devised consists of brick walls and 3-in. plank floor, plus 1-in. hardwood top floor, supported by 12 × 16-in. timbers of Georgia pine, of from 16 to 24 ft. span, spaced 8 to 11 ft. apart, and supported by Georgia pine columns, commonly of from 6 to 10 ins. in diameter, with cast-iron base plates and caps and pintles. The flat roof is also strongly advocated, mainly because of giving better standing ground for the firemen.

As the result of their experience the Factory Mutuals will insure a building with timber and plank floors and roof, if protected by automatic sprinklers, at a materially lower figure than a building of "fireproof construction" with floors of concrete or tile and girders of steel, which has no automatic sprinklers.

This sprinkler protection costs from 3 to 4 cts. per sq. ft. of floor and is thus obviously the cheapest form of "fireproofing."

Very truly yours,

John R. Freeman, Consulting Engineer.

Providence, R. I., July 29, 1903.

A NEW TRENCH DIGGING MACHINE.

For many years inventors have tried to perfect a trench digging machine that will work in tough as well as in soft soils. Most of the products of these inventors' brains have "died a-borning," a few have lived to be pictured in catalogues, but very few have ever done any actual earth moving on a large scale. While the machine illustrated herewith, Figs. 1 and 2, is called "new," it has the merit of having been in use some nine years, having been patented July 31, 1894, by J. B. Hill.

FIG. 1. THE BUCKEYE TRACTION TRENCH DIGGER.

As will be seen in Fig. 1, a wheel consisting of two rims, between which the buckets are mounted, is driven by chains and spur gearing. This wheel, instead of having an axle where the rotating power is applied, is supported upon rollers, and the power is applied to the rim of the wheel. There is a traction attachment so that the whole machine is self-propelling, and moves forward as fast as the digging progresses, the wheel being at the rear of the machine. Thus no weight comes upon the sides of the newly made trench. An endless belt elevator receives the material discharged from the buckets and conveys it off to one side, as shown in Fig. 2. Automatic scrapers or cleaners are provided to scrape any sticky material out of the buckets.

This machine, which is called the Buckeye Traction Digger, is made in four sizes, 11½, 14½, 20 and 24 ins., the size denoting the width of the trench that it cuts. The two smaller sizes cut a trench up to 4½ ft. deep, the 20-in. size cuts 5½ ft. deep, and the 24-in. machine cuts 6½ ft. deep. The manufacturers have recently made a special digger to excavate a trench 54 ins. wide by 8 ft. deep.

It is claimed that these machines will not only excavate ordinary earth, but will handle hardpan and shale as well. One operator and a fireman constitute the crew, and it is claimed that 130 to 330 ft. of trench per hour can be excavated in ordinary earth, according to the depth. A record of 11 ft. of trench cut 2 ft. wide by 3½ ft. deep in one minute is given for one of the large machines; and one machine has a record of 95,400 lin. ft. of trenching to its credit.

For photographs and information we are indebted to the manufacturers, The Van Buren, Heck & Marvin Co., 118-132 Fair St., Findlay, Ohio.

THE PROPOSED FORTH-CLYDE SHIP CANAL, SCOTLAND.

The construction of a ship canal connecting the Forth and the Clyde across Scotland has, as many of our readers know, been discussed at intervals for a number of years. Recently, however, the project has been taken up with more than usual earnestness, and it is stated that London and Edinburgh capitalists stand ready to pledge £10,000,000 for construction if Parliament will guarantee the interest on the capital. This cost estimate is based upon preliminary surveys made by the well-known engineering firm of D. & C. Stevenson, of Edinburgh, which is now making detailed surveys and preparing plans for construction. The project as planned is discussed by Mr. David Allan Stevenson, as follows:

The east and west coasts of Scotland are now connected by two canals, namely, the Forth and Clyde, from Grangemouth, on the Forth, to Bowling, on the Clyde, and the Caledonian, constructed at national expense, between Inverness and Fort William. Both of these canals are quite inadequate to meet the present wants of shipping, as they can only accommodate vessels of a small class. The first named is mainly used by barges, while the Caledonian can only be used by vessels of about 150 ft. in length, 28 ft. beam, and 17 ft. draft. Both canals are seriously incumbered by numerous locks.

At present all vessels bound from the east to the west coast of Britain, or vice versa, have to pass around the end of the island, through the Pentland Firth, with its rapid tide and dangerous sea, combined with deceptive currents and prevalent fogs, or "south about" through the overcrowded English Channel, so frequently the scene of disastrous collisions. It cannot be doubted that a ship canal through the narrow neck of land which separates the east and west coasts of Scotland, capable of carrying the largest vessels, would not only obviate all the dangers and delays incident to the "north about" and "south about" routes, but would effect much saving in time, in the cost of insurance, in wear and tear of vessels and their engines, and hence in the cost of transit; it would also for strategical purposes be of the greatest importance.

In designing such a canal the first points to be settled were: What are the essential requisites? These may be stated as follows: (1) That it should be of such dimensions as to admit ships of the largest class of merchantmen, and also vessels of the royal navy, passing freely and with perfect safety from sea to sea, practically at all times of tide. (2) That it should be as free as possible from locks, hydraulic lifts, or other mechanical appliances, involving possible delay or risk to ships using it. Having assumed these, as I think, indispensable conditions, the next question for solution was: Can a route be formed from the German Ocean to the Atlantic which fulfills them, and also can the canal be formed at a cost which will prove remunerative?

Fig. 2. Showing the Buckeye Trench Digger in Operation.

After careful study of the country and the levels, the

conclusion was arrived at that a route along the valley of the Forth gives the only practical solution of the problem. There is a tract of country extending from Alloa, on the Forth, westward along the valley of the Forth to within about 10 miles of Loch Lomond, where the surface of the ground is only from 30 to 50 ft. above mean sea level and the stratum is an alluvial deposit. Between this and Loch Lomond the ground rises rapidly and attains a maximum height of 236 ft. above mean sea level and dips again to the south end of Loch Lomond, the surface of which is only 22 ft. above mean sea level. The distance across this higher ground, from the 50-ft. contour on the one side to the 50-ft. contour on the other, is about 8 miles, 1¾ miles of it being above the 200-ft. line.

Loch Lomond (which has ample depth for vessels of the largest draft) is to be utilized as canal toward the north end of the Loch to Tarbet, and thence across to Loch Long there is only a distance of 1¾ miles, the ground attaining a maximum height of 130 ft. above the mean sea level. Loch Long is practically the Atlantic Ocean, and the navigation of it is safe and the water of ample depth. This, then, is the route proposed by my firm, and the surface of Loch Lomond, which as I have said is only 22 ft. above the mean level of the sea, is the proposed summit level of the canal, and having a water area of 21,000 acres and ample gathering ground—200 square miles—it would form an inexhaustible reservoir for supplying the locks with water. Only two locks at either end, at Alloa and Loch Long, would be required, as the level of the canal is only 13 ft. and 17 ft. above high-water level at these places, respectively. The exact route to be chosen will, of course, depend upon more minute inquiry than has yet been made.

The eastern approach to the canal, which will be tidal, will be formed by deepening the Forth or making a cut inland, with a depth of 25 ft. at low-water spring tides, from opposite Grangemouth to the locks which it is proposed should be placed about two miles above Alloa. This will give a depth of 43 ft. at high-water spring and 38 ft. at neap tides. The distance from Grangemouth to Alloa is six miles. From Alloa the canal will pass to the north of the links of Forth and to the northward of the town of Stirling, then along the valley of the Forth to Gartmore and enter Loch Lomond near the mouth of the Endrick, a distance of 29 miles.

Near the Loch Lomond end there are five miles of high ground, which, according to the geological survey, is the old red-sandstone formation. This part of the work will be open cutting. The distance from the junction of the loch and canal to Tarbet is 14 miles, and across the neck of land to Loch Long 1¾ miles. Loch Long is 15 miles in length to its junction with the Firth of Clyde. The total distance from Grangemouth to the Firth of Clyde is 65¾ miles.

Regarding the dimensions of the canal, it is essential to its success that it be made on a large scale and free from locks, excepting at the seaward extremities. As the level of the water of the canal will be only about 13 ft. above high water, one lock will be sufficient at high water, but two may be necessary at other times of tide. It is proposed to make the canal throughout with a depth of 50 ft., with a width at the bottom the same as the Suez Canal—namely, 72 ft.—and side slopes varying with the nature of the material. The locks will be capable of passing the largest vessels afloat, or about 600 ft. in length and 80 ft. in width, with smaller locks alongside for smaller vessels.

It would have been desirable to have proposed a canal of sufficient width to allow two of the largest vessels to pass each other at any place on the route; but in roughly estimating the cost it was found that this would involve so large an expenditure as to make it doubtful whether such a work would, in the meantime, prove remunerative. Frequent passing places, however, will be made at suitable intervals.

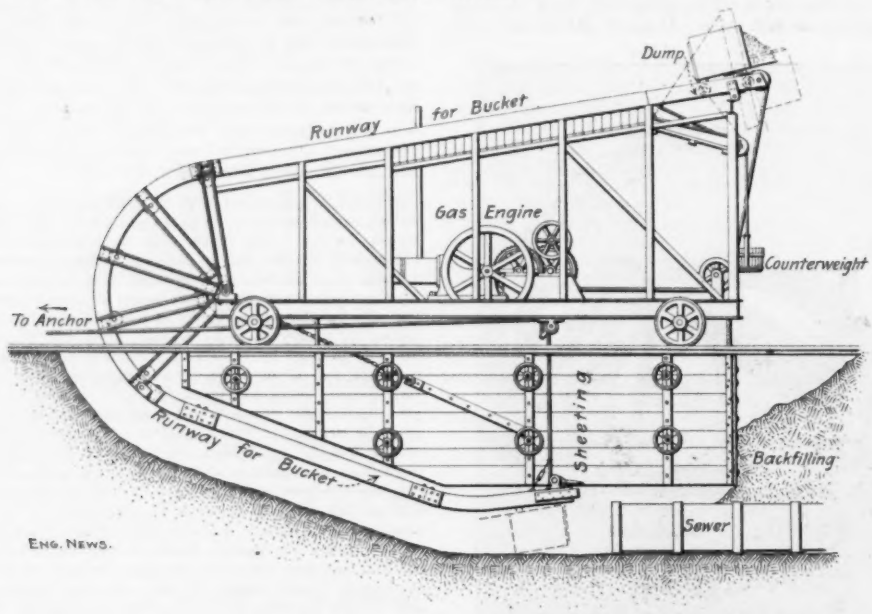

FIG. 1. TRENCH EXCAVATING AND BACKFILLING MACHINE.
Libbe Engineering & Contracting Co., Toledo, O., Builders.

There are no very serious difficulties to be overcome, though the cutting is no doubt a heavy one. There are few railways or road crossings of any importance, and the excavations are largely in soft material and the disposal of the excavations could be easily and cheaply effected, owing to the proximity to the canal banks of waste ground.

The cost of the undertaking cannot be more than approximately estimated without particular investigation as to the nature of the strata in the line of the canal; but my firm estimate the cost of the Tarbet route, with their present knowledge derived from the ordnance and geological surveys, and including interest during construction, at £10,000,000 ($48,665,000). The cost of management and maintenance my firm estimate at £60,000 ($291,990).

The saving in distance that would be effected may be stated thus: (1) From the Clyde to ports on the east coast of Scotland, northeast of England, and northwest of Europe the distance saved would be from 529 miles to 238 miles, in the majority of cases the distance being much more than halved. (2) From the Forth to ports on the west coast of Scotland, northwest of England, Ireland, America, and the Mediterranean the distance saved would be from 487 to 141 miles; in all cases, except the American and Mediterranean route, the distance being more than halved. (3) Tyne ports to the St. Lawrence River, the distance saved would be 150 miles. (4) West of Britain and northeast of Ireland to middle western ports of the Continent, the distance saved would be from 377 to 98 miles.

TRENCH EXCAVATING AND BACKFILLING MACHINE.

The slow and laborious work of excavating sewer and other trenches by manual labor has led to the introduction of special machines for excavating the trench and handling the material. In the machine described below, the excavation is performed by a bucket or dipper similar to that of a dipper dredge, the bucket running on a traveler which is carried forward as the work progresses, and from the rear of which the material excavated at the breast may be dumped as backfilling. If an open trench is desired, an arrangement is provided for depositing the material at either or both sides of the trench. Suspended from the frame of the traveler is a sheeting or lining, set up by screw trench braces which are released when the machine moves forward. This dispenses with the use of the ordinary sheeting and bracing, all work being done under its protection, and no timber being left in the trench. This machine is the invention of Mr. J. H. W. Libbe, President of the Libbe Engineering & Construction Co., of Toledo, O.

The general design and construction of the machine are clearly shown in Fig. 1. A steel carriage 30 ft. long is mounted on flanged wheels running on a track of 12-ft. gage, which can be easily varied according to the width of trench. Upon this carriage is built the steel frame supporting the runway for the dipper. This runway is lowered into the trench for any desired depth of cut, the upper and lower legs being connected by a curved portion of 15-ft. radius. Within the runway travels a trolley to which the bucket or dipper is attached, and a steel cable is led from the bucket to a drum driven by a 20-HP. steam or gasoline engine mounted on the carriage. At the rear end of the upper part of the runway is a pivoted section forming an automatic dumping platform, the weight of the loaded bucket tilting the platform, which is returned to position by a counterweight. The empty bucket returns by gravity to the bottom of the trench. The illustration, Fig. 1, shows the traveling sheeting in position, with the hand wheels for operating the cross braces. The sides are left very smooth and true. The sewer pipe or other material is lowered through the carriage, and the men engaged in laying the pipe are thoroughly protected by the sheeting. The machine is fed forward after each cut by a cable anchored ahead, and wound upon a drum operated by the engine.

In work at Toledo, excavating a trench 3 ft wide and 13 ft. deep in hard pan and blue clay, the machine handled about 1 cu. yd. per minute. An engineman and two laborers attend to all the operations. The weight of the machine complete, with engine, is about 10 tons. A canopy over the machine protects the work during bad weather.

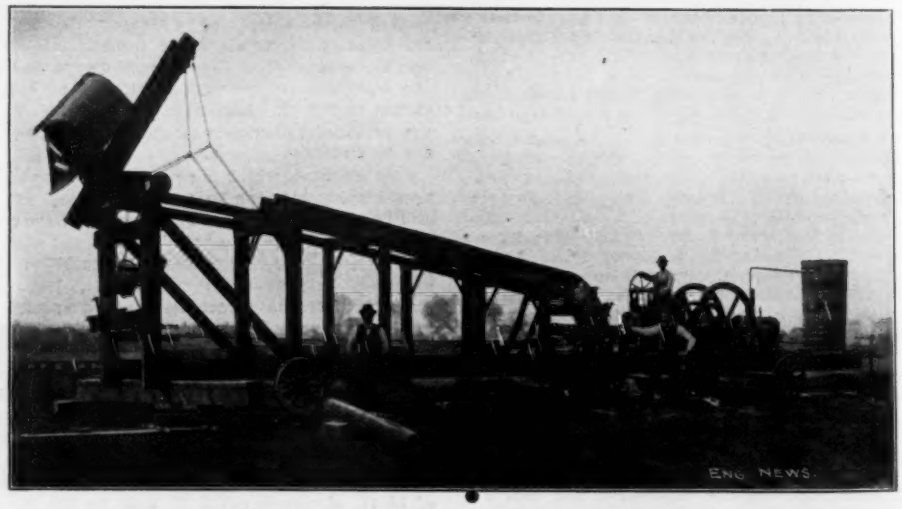

FIG. 2. THE LIBBE TRENCH MACHINE.

Fig. 2 is a view of the first machine built, in which the gas engine was mounted on a separate frame, but this has been changed to the more compact arrangement shown in Fig. 1. The view in the trench, Fig. 3, shows the guides or runway of the bucket, and the smooth surface of the sides; it also shows the sheeting and braces in place.

STREMMATOGRAPH TESTS OF FIBER STRAINS IN RAILS UNDER MOVING LOCOMOTIVES.*

By P. H. Dudley,† M. Inst. Min. Engs.

The large unit fiber stresses which occur in rails to carry their loads show that the entire permanent way for our best steam railroads is flexible and elastic by construction. The rails, cross-ties, and ballast resting upon a compressible, elastic or plastic sub-grade, are forced down by the moving loads and generated forces of the locomotives and cars, as they run over the track, until the total resistance equals the effects of the superimposed loads. The rails and cross-ties are depressed by the wheel loads in the ballast from ⅛ to ¼-in., under the present heavy locomotives and cars. The compression of the ballast and sub-grade forms one-third to one-fifth of the total amount of the temporary subsidence of the rail. The sub-grade is affected to a depth of 12 to 20 ft., according to its material, construction and stability. There is a characteristic "general depression" of the rails, cross-ties, ballast, and sub-grade produced by each type of locomotive or car, to carry and distribute the loads, with specific deflections in the rails under the wheel contacts.

In our present tracks the rail section acts as a continuous girder, and resolves the forces due to the moving wheel loads into horizontal components of strain in the base and head of the rails, which is partly continued through the splice bars from one rail to the next, to carry and distribute the wheel loads. The web of the rail also carries shearing strains at the points of flexure. In the section of the rail the neutral surface is neither elongated nor shortened by the deflections in the resolution of the components of strain. In the head of the rail immediately under the wheel contact the metal is in compressive strain above the neutral surface, while below the metal is in tensile strain. A strain of one character above or below the neutral surface is balanced by an opposite one in the section. The examination of a Stremmatograph record of the unit fiber strains in the rails, shows that they are a series of alternating strains of tension and compression, as the wheel loads and their spacing move over that particular portion of the rail.

The Stremmatograph was designed to determine the actual unit fiber strains in rails, and their distribution, under moving locomotives, cars and trains. It must be, by theory and construction, an instrument of precision, and owing to the character of the unit fiber strains which take place in the rail, able to segregate the portion of it under which a test is to be made. The instrument must be capable of recording any extension of the metal due to its elasticity of tension or compression, with precision, in the length segregated, and incidentally, as soon as the strain of one character is reversed, to record its opposite or absence in the same portion of the rail.

One of the important functions of the Stremmatograph is to record autographically, on a phosphor bronze slide, the distribution of the unit fiber strains in the base of the rail under the wheel base of the locomotive or car. Subsequently, by the microscope, the ordinates of the strains can be measured, which will show whether the curve was continuous or discontinuous for the entire wheel base of the passing locomotive or car.

STREMMATOGRAPH TESTS.

The tabulations of tests Nos. 257 and 271 are from the series of precision made to ascertain the distribution of stresses under the moving locomotives. Comparative tests for this purpose, made at different places, all agree as to the total stresses under the eight-wheel type of locomotive, with rigid trucks, within 0.5%; the total stresses for the same locomotive on the different dates compared also within 0.5% in total amounts. In test No. 257 the forward truck wheel produced the greatest tension, while in the following test, of Dec. 30, it was the rear truck wheel. The position of the counterweights, however, in passing over the Stremmatograph, were different on the two days.

Locomotive No. 870 is of the eight-wheel type, and in the forward and backward stroke there is a slight movement of the front of the engine, due to the application of steam to the driving wheels. In the forward stroke the tendency is to pull down the front of the engine slightly over its center of gravity, while in the backward stroke the tendency is to raise it on the springs. These effects will load the truck, as it passes over the Stremmatograph, in a different manner, and affect the unit fiber strains. The compression in front of the truck wheel, in test No. 257, was 709 lbs., and the tension under the wheel 13,463 lbs. On Dec. 30, in test No. 271, the compression in front of the truck wheel was 1,653 lbs., and under the truck wheel the tension was 8,976 lbs. In test No. 257 the depression of the rail from its normal surface to the loaded position was by a long flexure, the wave preceding the pilot wheel being slight. This was a characteristic of eight tests out of eleven on the same date. The front truck wheel was reducing most of the looseness of the superstructure. In test No. 271, on Dec. 30, both truck wheels were reducing the looseness, the wave in front of the pilot wheel being more decided than for the tests on the 23d. The thermal stresses in the rails, on the two dates, were not identical, as the variations in temperatures show, and would have some influence in the modification of the depression of the rail from its higher, unloaded surface, to that of the loaded condition in the "general depression." With the thermal stress of tension in the rails, in the falling temperatures, before the ends render in the splice bars, the looseness of the superstructure becomes less, and increases in rising temperatures when the thermal stress changes to compression before the rails render in the splice bars, due to expansion.*

The small compression stresses in front of the truck wheels show that in lowering from the unloaded to the loaded position they are moderate, as a long portion of the rail is gradually depressed. Under the specific deflections in the "general depression," the stresses of tension, and particularly those of compression, increase. It will be noticed that the compression between the rear truck wheel and front driver, in test No. 257, was 3,779 lbs., and in test No. 271, 4,252 lbs. These compression stresses are not large, for a 5⅛-in. 80-lb. rail, and indicate that the track was in excellent condition. The relief of the strain in the rail in the forward truck wheel, in test No. 257, is unusual.

The only stresses which are alike in the two tests were those under the front drivers. The tension was 26,926 lbs. of unit fiber stress, which is not large for rails, though three times that which is considered permissible in bridge members; where the ultimate strength of the steel is only

Fig. 3. Trench Cut by the Libbe Machine.

(Showing Bucket Runway and Side Sheeting which advance with the Machine.)

from 58,000 to 65,000 lbs., but little in excess of the elastic limits of the steel in the rails under test.

The stresses due to the tender become a part of those for the engine, in holding and continuing the "general depression" of the rail for the driving wheels.

The drawbar-pull of the engine is continued and transmitted by the tender to the train. This becomes an important factor in distributing the stresses of the engine, incident to its load for adhesion, and the effect of its expended tractive effort to a longer portion of the track than that occupied by the driving wheel base.

The increase in the stresses of the engine due to its expended tractive effort, in the eight-wheel type, is 15 to 30%, according to the work performed. At this location the light engine would produce a total stress in the base of one rail of 108,000 to 110,000 lbs. The greatest total amount for the tests of the day, Dec. 23, Test No. 257, was 154,620 lbs., locomotive No. 934, same type and class as No. 870, drawing the Fast Mail, 13 cars, speed 48 miles per hour. Under the front driver the unit fiber stress was 37,082 lbs. Larger unit fiber stresses than those given are frequent.

In the first column of the tabulations of the tests are given the unit fiber stresses in the base of one rail, both of compression and tension. In the second column the total is given for the wheel base of the trucks and drivers of the engine, as well as for the tender and cars. In the third column, the unit fiber stresses per wheel base of the engine and tender. In the fourth column, the total stresses for the entire locomotive, or a car.

In comparing the results of two locomotives of the same or different types, the total stresses are used in each case, and in the series of tests of precision, for the determination of the distribution of the stresses under locomotives, only those were used in which the conditions were practically alike. This has occupied several years of time, to reduce and repeat the tests, to secure total results agreeing within less than 0.5% with a class and type of engine. The results show that the distribution of the stresses under the locomotive as subdivided by the different sub-wheel bases, should correspond closely to the total sum of the stresses as though distributed from the center of gravity of the entire locomotive. This has been found to be the case with the best designed locomotives in good condition with rigid front trucks. If we were able to determine precisely the stresses due to each sub-wheel base, the total should equal those obtained for the entire wheel base of the locomotives. As the sub-wheel bases pass over the Stremmatograph, equalizing of the loads is occurring, so that a calculation would be required to show what the total should be for each wheel base. This prescribes considerable data which is not yet available in making such tests, and it becomes necessary therefore to compare the total stresses, for the purpose of precision. That the sum of the effects of each wheel base should equal the stresses for the entire wheel base, is in accordance with a well-known law of mechanics.

These tests of precision have been made to see how closely the locomotive as a machine and generator is capable of distributing and repeating its stresses upon the best track. Such results as have been acquired in the tests of precision, can be obtained only on a high standard of track, with efficient joints, and locomotives in good condition.

In the fifth column is given the unit fiber stress per pound of load in the base of one rail for the sub-wheel base of the drivers and trucks of engine, tender or cars.

The figures are approximate only, yet they furnish the instructive information in respect to the distribution of stresses under the supposed static wheel loading of the sub-wheel bases of the locomotive. When it is running, owing to the undulations in the track, also to movements of the wheels in their pedestals, and the irregular application of steam to the driving wheels, it is impossible to expect results corresponding to its supposed static wheel loading. As stated, we have a flexible or elastic track, with looseness of the rails upon the cross-ties. This must first be reduced by the weight under the forward truck wheels, which at once modifies the effect of the calculated static wheel loads of the locomotive. If the tracks were inflexible, except for the strains in the rails to support the loads, then we should obtain unit fiber stresses corresponding to the supposed static wheel loading of the engine, except for the driving wheels.

It will be instructive to observe that the unit fiber stresses per pound of load in the rails under the forward trucks, carrying about one-half of the weight per axle of the driving wheels, are within one-fifth as much as those under the drivers, even with their added effect of the expended tractive effort. In other words, by a subdivision of the total load of the engine, a part may be used to stiffen and strengthen, not only the superstructure, but the sub-grade, to carry and distribute the heavier driving wheel loads with less deformation than would be possible without the forward truck. In the ten and twelve-wheel types of engines, for slow speeds, even more favorable results are secured. In some tests under twelve-wheel engines, at 15 miles per hour, under the forward truck, the unit fiber stress per pound of load was one pound, which reduced to 0.7 of a pound for a total load of 140,000 lbs. on the four pairs of driving wheels.

The forward truck under the front of the engine adds to its value and efficiency as a machine, for locomotion, and is distinctly an American invention. It was designed first by Mr. John B. Jervis, in 1831, for an engine for the Mohawk & Hudson Railroad, and was under construction that year, and went into service in 1832. A plan for a similar truck engine was also sent to R. Stephenson & Co, Newcastle-on-Tyne, England, for construction, and was received and run on the Schenectady & Saratoga Railroad in 1833. This was the inception and installation of the American theory and practice of subdividing the total load of the engine, and utilizing a portion of the weight by a forward leading and guiding truck, to take up the looseness of the track and stiffen the portion of the rail occupied by the heavier loads of the driving wheels. The "general depression" of the rail started by the forward truck wheels is continued under the driving wheel to the rear portion of the rail, held down by the following wheels of the tender. With this principle of distributing the loads of the locomotive, the greater weights carried upon the driving wheels do not produce a proportional increase of stress incident to the expenditure of their tractive effort and the load carried upon the driving wheels. The rail instead of forming a deep depression under the driving wheels, is retained in a more level and uniform height in the general depression than would be the case

*A paper read before the American Society for Testing Materials.

†90 Pine St., New York City.

*Nearly all rails break under the locomotives, during the decided falls in temperature, before the rail ends have rendered in the splice bars. Loosening some of the bolts in the autumn and readjusting the rails, relieves them of tension, and has reduced the percentage of broken rails.

TABLE I.—Showing Record of Stremmatograph Test No. 257, made Dec. 23, 1899, on New York Central & Hudson River R. R.

Items.	Per wheel,	Fiber Stress on Base of Rail: Per wheel base of—Drivers and trucks of engine, tender and cars, lbs.	Engine and tender, lbs.	Locomotive and cars, lbs.	Per lb. of Wheel Base of Drivers and trucks of engine, tender and cars, lb.
	lbs.				
Compression in front of truck wheel	709				
Tension under front truck wheel	13,463				
Compression between front and rear truck wheel	709	23,857			1.072
Tension under rear truck wheel	7,086				
Compression between truck wheel and front driver	3,779		83,024		
Tension under front driver	26,926				
Compression between drivers	4,252	59,167			1.369
Tension under rear driver	24,564				
Compression between rear driver and front tender wheel	3,071			127,075	
Tension under front tender wheels	10,157				
Compression between tender wheels, front truck	0	20,904			0.931
Tension under rear tender wheel, front truck	8,031				
Compression between front and rear tender trucks	2,362		44,051		
Tension under front tender wheel rear truck	8,976				
Compression betweeen wheels of rear tender truck	472	23,147			1.031
Tension under rear tender wheel	11,337				
Compression between tender wheel and first car wheel	2,326				
Tension under front wheel of first car	9,684				
Compression between first and middle wheel	272				
Tension under middle wheel	12,754				
Compression between middle and rear wheel	1,417	34,756			1.310
Tension under rear wheel	8,503				
Compression back of wheel	945				
Compression in center of wheel space	0		.....	.....	
Compression in front of wheel of rear truck	2,362				
Tension under front wheel of rear truck	9,920				
Compression between front and middle wheels	1,181				
Tension under middle wheel	8,379	33,895			1.280
Compression between middle and rear wheel	2,362				
Tension under rear wheel	8,976				
Compression between trucks of first and second cars	709				

Note: Track, No. 1; location, 6° curve, 600 ft. west of mile post No. 10; rail, 5¼ ins., 80 lbs.; moment of inertia, 28.5; cross ties: length 8 ft., width 9 ins., thickness 6 ins.; wood, yellow pine; weight, 155 lbs.; 18 per 30-ft. rail; average weight of superstructure per yard, 449 lbs.; three-tie supported joints, 36-in. splice bars; stone ballast; train No. 51—Empire State Express; No. of cars, 4; weight, 430,000 lbs.; locomotive, No. 870 new; weight, 220,000 lbs.; speed, 42 miles per hour; temperature, 40°.

without the assistance of the weight upon the forward truck. In extending the same principle to larger types of locomotives, having more than two pairs of driving wheels, the effect of the distribution of the increased load of the locomotives upon stiff rails has been rendered exceedingly advantageous, as already indicated.

Each type of locomotive produces on the track a distinct form of the general and specific deflections under its wheels. The decided reduction in unit fiber stresses, and greater smoothness of the track, by the introduction of the stiffer rails, has made it possible within the last decade to draw heavy trains at high rates of speed. By the increased smoothness of the track incident to the stiffer rails, and the higher maintenance possible, the locomotive in running over the track has been able to expend most of its power in overcoming train resistance, without doing destructive work upon the track. If we examine the locomotive as a machine, in the distribution of its loads by the different wheels of the wheel base, it will be seen how important it has been to increase the smoothness of the track, so that the locomotive could run over it without generating destructive dynamic forces under each wheel. The center of gravity of the engine is nearly midway of its length, and as a rule below the center of its boiler shell. The center of gravity of the tender will be midway of its length and about 5 to 6 ft. from the top of the rails. The center of gravity of the locomotive will be vertically in line through the cab and below the center of gravity of the engine. With stiff rails and smooth track, with the force of the drawbar-pull between the engine and tender, the locomotive can distribute its load to the track nearly in accordance with its center of gravity.

To do this completely without the generation of destructive dynamic forces, each wheel should roll forward practically parallel with the surface of the rail, without undulations. The distribution of steam to the driving wheels will not be uniform, and some irregular motion will take place in their revolutions. The center of gravity of the engine should ride forward without undulations, also that of the tender. In such cases the center of gravity of the entire locomotive will move forward without much undulation. This high degree of perfection is seldom attained, though closely approximated.

If we examine the tabulation of the fiber stresses in the rail, we note that between the wheel contacts, as well as under the wheels, the rail is distributing its load by horizontal components of strains in the base and head of the rail. For the rail sections to perform completely the functions of a continuous girder, the joints of the rails must be able to continue the same functions as the rail section. It is necessary to support not only the rail ends, but prevent them from depressing and also from separating or closing between the wheels as the locomotive moves over the track. Rails in which the ends were supported by chair joints, would not be capable of transmitting the horizontal components of strain from one rail to the next. With efficient splice bars, bolted firmly, so that the rails will not render without a greater force than the strains imposed by the passing locomotive, then the bars are able to transmit, in a measure, the horizontal components of strain from one rail to the next; that is, they continue it between the wheels, and under the wheel which is passing over the joint.

For the most efficient distribution of the total load of the locomotive, the wheel base must have proper design so that the wheel spacings are not excessive. It is noticed often that the wheel spacing between the rear driving wheels and front truck wheels of the tender is so long that the rail is relieved nearly of strain under the locomotive. In such conditions, which may be observed on light rails, the engine forms a general depression, and the following tender also another depression. These are both greater than would be the case were the "general depression" formed by the driving wheels continued to the wheels of the tender.

The general idea that the span of the bending rail is in accordance with the tie spacing, is not confirmed. Owing to the looseness of the rails upon the cross-ties, the span of the bending rails is influenced by the wheel spacing of the locomotive, in distributing its load.

As the stiffness of the rails has been increased, the axle loads have doubled, within the past decade. The distribution of heavy loads upon stiff rails can be made without undue injury to the track. With the increased axle load, the intensity of the pressure between the wheel tread and the head of the rail is increased. The only way to relieve this is by a slight increase in width of head, and provide for it with proper physical qualities in the metal.

EFFECT OF WATER AND COMBINATIONS OF SAND ON THE SETTING AND STRENGTH OF CEMENT.*

By E. S. Larned.†

The personal equation, perhaps, may not be removed in testing cement, but other conditions that vitally affect the results can be brought to a more uniform basis, and these in ordinary practice may briefly be summed up as: the quantity of water used to produce a paste or mortar of given consistency; time and manner of manipulation; method of molding; temperature of water and air; time and conditions of exposure in air and water, and rate of applying the load. The effect of water in retarding the induration of cements and reducing their tensile strength, particularly at short periods, has long been known, and more or less information has been published as the result of experiments made.

The writer was led to make a series of tests on these lines in somewhat more detail than anything he had seen published, and it is the result of these experiments that he will now consider. It may be stated that one man made the briquettes for the entire series, six for each period, at each interval in the amount of water used. The water used in mixing was at an uniform temperature of 63° F., and the temperature of the air averaged slightly under 70° F., and fluctuated between 50° F. and 75° F. Two briquettes of Am. Soc. C. E. standard form were gaged at a time, and beginning with the dry mixtures the molds were filled in three layers, each rammed successively until flushed, by hand, using a hardwood pestle, and finally struck off and smoothed with a trowel. The ramming process continued until the mixtures became too soft when the molds were filled by pressing in with the thumb and troweling. So far as possible, the briquettes were allowed to set in air, under a damp cloth, about two hours after taking the heavy wire, before immersion. This could not be followed uniformly, and some of the softer mixtures were allowed to set in air over night and in a few instances the operator was obliged to wait late in the night to complete his observations. In determining the rate of setting, the Gilmore needles were used, and care was observed to use the same sample of cement throughout the series, and this was taken from the storehouse of contractors engaged in the construction of large public works. The decimal scale of weights was used in gaging, the graduate glasses being carefully calibrated to agree, and the briquettes were broken on a Fairbanks' machine of late pattern, the clips having roller bearings of composition metal.

Chemical analyses of the cements here considered were not made for this test, but the characteristics of the brands named are perhaps well known to many, and will be only briefly referred to. The Atlas and Giant brands of Portland cement both came from the Lehigh District of Pennsylvania, and in their chemical composition are in quite close agreement. The "Union," Natural, is also made from the crystalline cement rock of the Lehigh District, is light in color and its composition is quite unlike the "Hoffman," which is dark in color, being made from the magnesian limestone of the Rosendale District,

*Abstract of a paper read before the Cement Section of the American Society for Testing Materials.

†101 Milk St., Boston, Mass.

TABLE II.—Showing Record of Stremmatograph Test No. 271, Dec. 30, 1899, on New York Central & Hudson River R. R.

Items.	Per wheel,	Fiber Stress on Base of Rail: Per wheel base of—Drivers and trucks of engine, tender and cars, lbs.	Engine and tender, lbs.	Locomotive and cars, lbs.	Per lb. of Wheel Base of Drivers and trucks of engine, tender and cars, lb.
	lbs.				
Compression in front of truck wheel	1,653				
Tension under front truck wheel	8,976				
Compression between front and rear truck wheel	709	24,093			1.083
Tension under rear truck wheel	10,629				
Compression between truck wheel and front driver	4,252		79,835		
Tension under front driver	26,926				
Compression between drivers	2,834	55,742			1.249
Tension under rear driver	22,675				
Compression between rear driver and front tender wheel	2,362			127,781	
Tension under front tender wheels	7,558				
Compression between tender wheels, front truck	236	20,903			0.893
Tension under rear tender wheel, front truck	11,101				
Compression between front and rear tender trucks	1,653		47,946		
Tension under front tender wheel rear truck	9,684				
Compression betweeen wheels of rear tender truck	1,653	27,043			1.159
Tension under rear tender wheel	13,699				
Compression between tender wheel and first car wheel	2,362				
Tension under front wheel of first car	9,684				
Compression between first and middle wheel	2,362				
Tension under middle wheel	10,393				
Compression between middle and rear wheel	0	31,887			1.200
Tension under rear wheel	8,031				
Compression back of wheel	0				
Compression in center of wheel space	472		.....	.....	
Compression in front of wheel of rear truck	1,890				
Tension under front wheel of rear truck	8,031				
Compression between front and middle wheels	2,126				
Tension under middle wheel	12,046	38,619			1.310
Compression between middle and rear wheel	236				
Tension under rear wheel	14,172				
Compression between trucks of first and second cars	236				

Note.—Track, No. 1; location, 6° curve, 600 ft. west of mile post No. 10; rail, 5¼ ins., 80 lbs., moment of inertia, 28.5; cross ties: length 8 ft., width, 9 ins., thickness, 6 ins.; wood, yellow pine; weight, 155 lbs.; 18 per 30-ft. rail; average weight of superstructure per yard, 449 lbs.; three-tie supported joints, 36-in. splice bars; stone ballast; train No. 51—Empire State Express; No. of cars, 4; weight, 430,000 lbs.; locomotive, No. 870; weight 220,000 lbs.; speed, 44 miles per hour; temperature, 6°.

TABLE I.—Showing Tensile Strength of Cements, Mixed Neat with Different Proportions of Water.

Cement.	Water, per cent.	Sieve test residue on No. 50.	Sieve test residue on No. 100.	Sieve test residue on No. 180.	Wire minutes. Light.	Wire minutes. Heavy.	Tensile strength, lbs. 24 hours.	Tensile strength, lbs. Days. 7.	Tensile strength, lbs. Days. 28.	Tensile strength, lbs. Months. 3.	Tensile strength, lbs. Months. 6.	Tensile strength, lbs. Months. 12.
Giant Portland	15	0.15	5.4	21.2	12	207	371	655	875	941	720	787
	16	....	....	....	29	297	303	750	973	1008	735	816
	18	....	....	....	80	355	260	649	773	831	645	748
	20	....	....	....	142	402	233	500	693	716	621	676
	22	....	....	....	268	473	184	546	635	658	601	589
	24	....	....	....	327	912	167	539	649	644	629	755
Union Natural	23	0.1	4.6	10.2	13	32	212	251	252	311	275	356
	25	....	....	....	18	39	185	218	215	289	300	341
	27	....	....	....	22	42	150	188	220	257	272	314
	29	....	....	....	20	52	128	178	202	246	248	256
	31	....	....	....	21	57	112	173	199	224	250	300
	33	....	....	....	27	85	104	172	182	267	246	290
	35	....	....	....	38	137	93	121	178	200	286	319
	37	....	....	....	34	100	85	108	168	262	306	326
	39	....	....	....	67	233	85	119	202	252	371	400
Atlas Portland	13	0.1	7.0	18.0	13	270	366	775	859	1067	892	832
	14	....	....	....	18	303	404	780	891	972	852	781
	16	....	....	....	22	327	363	692	725	844	806	723
	18	....	....	....	15	383	308	570	723	785	728	724
	20	....	....	....	56	703	225	590	718	760	674	636
	22	....	....	....	52	833	166	554	649	731	643	604
	24	....	....	....	188	918	42	510	691	695	632	574
Hoffman Rosendale	23	2.3	12.4	21.9	22	59	138	177	271	332	284	264
	24	....	....	....	..	78	125	141	264	342	309	310
	25	....	....	....	35	120	150	164	216	308	318	321
	27	....	....	....	49	143	117	116	194	305	345	272
	29	....	....	....	76	166	96	105	164	272	320	267
	31	....	....	....	117	212	72	72	159	270	371	225
	33	....	....	....	115	235	62	71	147	277	379	244
	35	....	....	....	127	400	50	64	112	245	318	315
	37	....	....	....	198	828	59	62	96	...	284	351
	39	....	....	....	260	1057	54	56	85	...	355	364

Note.—Results shown are the averages of six briquettes made.

New York. "Union" more closely approaches the Portland standard in composition and differs from the "Hoffman" noticeably in its lime and magnesia content, having about 50% lime and 2% magnesia, while the "Hoffman" has about 36% lime and from 16 to 18% magnesia, which is characteristic of about all the New York Rosendale cements. The low magnesia content together with the very fine grinding of "Union" cause it to be more active and quicker setting than "Hoffman," and this is well shown in the table, particularly in the wetter mixtures.

As might be expected, this difference in the cements, tested neat, would be in greater contrast when combined with sand in concrete mixtures and it was, in fact, the dissimilar results in practical work of construction that led to this experiment, and I regret that the experiment did not also include mortar mixtures, in the proportion of two sand to one cement, wherein conditions would obtain more closely approximating the operations of every-day practice.

From personal acquaintance with a recent large work of concrete construction, the writer is forced to the conclusion, that, when any reliance must be placed upon the cohesive strength of Rosendale cement, within six months and perhaps longer, depending upon the exposure and local conditions, great care must be exercised in proportioning the amount of water used, or, in the present day of wet concretes, in selecting a cement that successfully withstands the deteriorating influence of an excessive amount of water.

In the table of tensile results (Table I.) the dryer mixtures of the Hoffman cement show superiority up to the 28-day period, at which time it is quite marked and uniform. The gain in strength between the 24-hour and 7-day periods, appears slow, and grows slower as the amount of water was increased. The improvement between the 7-day and the 28-day periods is better, but the rate of gain appears generally in favor of the dryer mixtures. The gain in all mixtures, between the 28-day and the three months' period, appears quite uniform and develops a rapid gain for the wetter mixtures. After the latter period inconsistencies develop, and between six months and one year only the 37% and 39% series show any appreciable gain and the wettest mixture appears superior at the end of the year, the others generally showing a falling off in strength for which I can offer no explanation.

In the "Union" cement series the dry mixtures generally appear superior at the 24-hour and 7-day periods, the rate of gain is quicker and quite uniform, as in the Portland cements, the gain in strength of the wetter mixtures is more rapid between 7 days and 28 days, the wettest mixture having passed four of the series next below, and all of the series being closer together than at the two earlier periods. At three months only the 23% and 25% series held their superiority, the wetter mixtures rapidly overtaking all others and being in close agreement with the exception of the 31% series, which made a slower gain. After this period peculiarities develop for which no explanation can be offered, but the uniform rate of improvement is noticeable in all instances, and the results at one year are better in each case than at any preceding period, the 23% and 33% series showing a falling off, between 3 months and 6 months, with a good recovery at one year.

In the Portland cement series, the rapid and uniform improvement between 24 hours and 7 days is noticeable, but the dryer mixtures generally hold their superiority. This is noticeably uniform in the Atlas cement at all periods, the maximum strength was attained at 3 months, after which, and up to one year, there appears a steady falling off in strength, but from 3 months on, the dryer mixtures are uniformly better.

The Giant cement also attained its maximum strength at 3 months, at which period the dryer mixtures also appear uniformly superior with the exception of the 15% series, and judging from the results of this series throughout the test, it would appear that there was not quite enough water used to perfect the crystallization of the cement. The Giant cement also shows a falling off between 3 months and 6 months, but a good recovery after this latter period in all but one series, 22%, and the wettest mixture, 24%, passed the three series next below at one year, two of them in fact at six months, and between six months and one year it shows a more rapid gain than any of the other series.

The personal equation is apparent in these tests, as in any test of the tensile strength of cements, but every effort was made to secure consistent and uniform results, and I will repeat that one man made the test throughout the entire series for the four cements named.

A table (Table II.) is added, showing the tensile strength of cement mortars in the proportion of one part of sand to one of cement, by weight, for Rosendale or natural cements, and two parts sand to one cement for the Portland. A silicious sand was selected for this test, carefully screened to the sizes noted, and combined in the proportions given in the table. The test was made to determine the relative value of sand grains of different diameters, in combination with cement, and also to study the effect upon the tensile results of adding fine material.

Few unwashed natural sands are free of dust of a loamy or clayey nature containing a high percentage of organic material, and in specifications, usually calling for sand, clean and sharp and free from fine material, the importance of excluding this deleterious agent is recognized, but it is not always possible to enforce this absolutely, and from mechanical analysis of a large number of samples, and casual inspection of sand in use at various points, I am satisfied that much sand is used that contains 5% dust and a good deal that carries as much as 10% and even more in some instances.

The fine material passing the No. 100-mesh screen, used in this test, was obtained from a clean white silicious sand, and if, with increasing amounts of this material, a falling off in tensile strength appears, it can, in no sense, be taken as a measure of what would follow by using sand containing a dust of loamy or clayey nature, but is in a way suggestive. The cements used in this test were of the same sample as in the other tests previously referred to.

The sand mortar test is the true basis upon which to judge the value of a cement, and I believe the proportion of sand to cement should be the same as employed in the actual work of construction. Unfortunately, this was not carried out in the above test of the natural cements for the reason that results were desired, for purposes of comparison, with previous tests in the same laboratory, in which the crushed quartz or standard sand was used in the proportion of one part sand to one of cement.

Explanation of the results is hardly required. It will be noticed, particularly in the natural cements, how uniform and constant is the falling off in strength at the seven day period, as the amount of fine material increased. This tendency, in the case of Union, disappearing at the 28-day period, at which time rather remarkable uniformity is found in all the combinations, except the 100% "Fine." Serious retardation in the improvement of the Hoffman, with the addition of fine material in the sand, is noticed between the 7-day and 28-day periods, the mixtures containing over 5% "Fine" remaining almost latent for this time, three of the combinations showing an actual loss, while four make a small gain, the average gain being two pounds. A rapid recovery is found, however, in these combinations between the 28-day and 6 months' periods, and it is to be regretted that longer time tests were not made.

A tabulation of the results, excluding the series in which all "Fine" and crushed quartz were used, is given herewith:

	7 days Aver.	7 days Max.	7 days Min.	28 days Aver.	28 days Max.	28 days Min.	6 months Aver.	6 months Max.	6 months Min.
Hoffman	84	118	62	99	163	70	277	316	221
Union	139	156	108	198	222	183	336	362	302

The effect of the fine material upon the Portland cement is not so noticeable, even at the shortest period, except in the series with 100% and 50% "Fine," and no parallel can be drawn between the test with Portland cement and the results with Rosendale cement using the same combinations of sand.

All of the above tests were made under the supervision of the writer while Division Engineer with the Metropolitan Water and Sewerage Board (Mr. F. F. Stearns, Chief Engineer, Boston, Mass.), and he desires to make proper acknowledgment of the privilege of using the information given above.

TABLE II.—Showing Tensile Strength of Cement Mortar with Sand Grains of Different Diameters. Results given are the Average of Six Briquettes.

Sand gage, per cent. used. No. 30.	No. 20.	No. 100.	Fine.	Natural cement mortar 1:1 Union Water per cent.	Union Days 7.	Union Days 28.	Union 6 mos.	Hoffman Water per cent.	Hoffman Days 7.	Hoffman Days 28.	Hoffman 6 mos.	Portland mortar, 2:1 Giant Water per cent.	Giant Days 7.	Giant Days 28.	Giant 6 mos.
100	...	...	...	17	156	193	352	15	115	163	314	10½	286	288	412
...	100	...	...	17	151	194	349	15	118	146	286	10½	294	331	473
...	...	100	...	17	153	187	340	15	91	110	257	10½	201	226	294
...	...	...	100	17	100	123	307	15	71	76	186	10½	129	159	223
80	10	10	...	17	154	210	358	15	94	124	301	10½	301	380	486
70	15	12½	2½	17	142	190	332	15	86	107	254	10½	301	303	428
60	20	15	5	17	143	192	342	15	83	107	285	10½	307	311	419
50	25	17½	7½	17	140	208	345	15	80	89	291	10½	391	400	538
40	30	20	10	17	133	197	362	15	90	82	296	10½	350	355	475
30	25	30	15	17	123	191	329	15	78	77	266	10½	362	359	478
20	20	40	20	17	128	199	318	15	66	73	285	10½	317	374	480
10	15	50	25	17	122	201	324	15	68	72	221	10½	291	354	488
50	..	..	50	17	108	193	317	15	62	70	239	10½	247	287	351
50	50	..	..	17	154	222	323	15	82	107	316	10½	440	408	542
50	..	50	..	17	150	210	344	15	78	88	290	10½	309	336	438
25	25	25	25	17	125	183	302	15	74	68	250	10½	279	337	447
Crushed quartz.							3 mos.				3 mos.				3 mos.
40	..	60	..	16	179	256	355	14	93	100	142	9½	257	331	351

All proportions and percentages determined by weight. Natural sand used, first passed through No. 8 screen and residue excluded. No. 30 sand passed No. 20 screen and caught on No. 30 screen; No. 20 sand passed No. 8 screen and caught on No. 20 screen; No. 100 sand passed No. 30 screen and caught on No. 100 screen; "Fine" is clean white sand sifted through the No. 100 screen.

REPORT OF THE COMMISSION OF THE JEROME PARK RESERVOIR.

A commission, consisting of Prof. William H. Burr, chairman; Mr. John R. Freeman and Mr. Rudolph Hering, members of the American Society of Civil Engineers, was appointed by Mayor Seth Low to report on certain engineering features of the Jerome Park Reservoir that had been severely criticised by a committee of the Merchants' Association. Mr. Hering was not conferred with in making the report on account of his absence from the city. As the report is an admirably written engineering document, containing many features of exceptional interest, we give it in full.

PREAMBLE.

In February last, certain questions of engineering construction connected with the completion of the Jerome Park Reservoir were referred to this Commission for consideration and report by the Mayor of the city at the request of a Committee of the Merchants' Association.

These questions involved many examinations, including tests of portions of the work now in progress at the reservoir site. It has been necessary for this Commission to give these matters much study at such times as might be available without too serious interruption of the work for which it was originally created. For these reasons our report has necessarily been delayed, and even at this time we are unable to transmit more than a report upon the two principal subjects submitted to us. We hope to report upon the remaining subjects within a short time.

What may be termed the two most important subjects submitted to us, in consequence of their bearing upon the immediate progress of work, are the treatment of the bottom of the reservoir and the examination of the breast or side walls of the reservoir already constructed, which have been subject to much criticism, and our present report will be found completely to cover them.

THE BOTTOM OF THE RESERVOIR.

In submitting this report, we desire it to be understood that our opportunities for making detailed examinations of the character and probable imperviousness of either the rock or the earth portions of the reservoir bottom have been extremely limited by reason of the covering of quarry chips, sand, top soil and debris. We have made such examinations of both classes of bottom as the time and facilities at our disposal have permitted. In doing this, we have had three areas of 100 sq. yds. each of rock bottom cleared, but these three combined areas make little more than 1-10 of 1% of the entire rock bottom. The rock surface revealed by these three clearings appeared close and dense in texture, but at some other points, notably at one point where excavation is now being made at the southwest corner of the west basin and at another point in the outcrop not far from the overflow, the rock is much broken and fissured and contains badly disintegrated spots, indicating what must be guarded against in the rock bottom where now concealed from view by quarry, debris and standing water. The depressions in the rock made by the blasting and shown at these clearings appear to be deeper than contemplated in the contract drawings. The earth portions of the bottom are mainly of sand overlying bedrock 10 to 20 ft. below the finished reservoir bottom, but in this there are considerable areas of soft or miry material. In some places the true character of this earth bottom is obscured by top soil and quarry debris shaken from cars. The methods of treatment to be indicated in our report, therefore, must necessarily be typical or general in character, leaving to the responsible engineer in charge the duty of making the necessary adaptations for the varying conditions as they may develop in the progress of the work.

The following recommendations apply to the west basin. They are general in character and may be applicable to either basin, but they should be considered subject to such modification or adjustment in detail as experience in the progress of the work may indicate to be advisable.

The construction of the reservoir bottom naturally divides itself into four parts:

1. Rock bottom.
2. Earth bottom.
3. The irregular strip where the earth and rock meet.
4. The strip immediately adjacent to the inside of the embankment wall or slope.

ROCK BOTTOM.

The entire rock bottom is composed of gneiss varying greatly in texture, although the greater part is probably dense and sound. This class of rock is liable to be fissured, and experience with other reservoirs built on it shows that it may be subject to serious leakage. We have noted that in some places the material now filling the depressions in the rock is loose and porous. We therefore recommend that the entire rock surface be thoroughly cleaned by removing all quarry chips or other debris, sand and loam; that water be removed from all depressions prior to depositing any mortar or concrete; that all soft or disintegrated portions be removed, and that all loose fragments be barred out, if necessary, and the rock surface washed clean. All crevices or fissures should then be thoroughly cleaned out so as to leave a clean rock surface at all points. This treatment should be given to all the natural rock surface at or near sub-grade as well as to the new surface created by blasting or other excavation. The crevices and fissures revealed by this cleaning of the surface should be filled with a rich concrete containing nothing larger than 1-in. stone, or, if small, with cement mortar. In general, a coating of Portland cement concrete made from the entire product of the crusher, including broken stone and dust, with sand added if necessary, so as to contain the proportions prescribed in the contract (1, 3, 4) with sufficient water to make a wet mixture, should be applied to these exposed surfaces of rock so as to fill solidly all cavities to a depth of at least three inches. Before applying this concrete, the rock surface should be thoroughly wet. For the purpose of closing any minute cracks, all projecting portions of the rock surface not covered with concrete or mortar in the above process should be brushed over with a grout of neat cement left to set for 24 hours before sand is filed over it. The depressions remaining below sub-grade and above this concrete covering may be filled with a lean concrete or with sand or fine gravel, as may be prescribed by the engineer, to the sub-grade, the filling material in any case to be well tamped and put in place so as to make the most compact and solid mass practicable. Over the entire rock portion of the bottom prepared in this manner, we recommend that there be placed a layer of concrete 4 ins. in thickness of the proportions prescribed in the contract, the top of which shall be at the finished grade so that at no point shall its depth be less than 4 ins., except where high points of ledge rock may project into it not more than 1 in. This 4-in. layer of concrete should be put in place wet, and should be so treated by tamping or by other means as to give the closest and densest mass practicable. In doing this the mortar should flush to the surface and be compacted and smoothed to a moderate degree with a float or other tool to increase its imperviousness.

EARTH BOTTOM.

The earth portions of the reservoir bottom should be excavated 8 ins. below the grade prescribed for the upper surface of the finished concrete where the earth is practically clean sand or of a nature to afford equivalent supporting power. In those portions where the earth is soft, the material must be excavated to such depths as the engineer may prescribe, and be refilled with sand or gravel well tamped so that those portions shall have a bearing capacity equivalent to that of firm sand. After the completion of this preparation of the earth portion of the bottom, a layer of concrete of the composition prescribed in the specifications 8 ins. in thickness should be put in place. This concrete should be mixed wet so that with little tamping or other method of compacting it shall make the densest mass attainable. The upper surface of this concrete should be finished in the manner prescribed for that over rock.

THE STRIP WHERE EARTH AND ROCK MEET.

The weight of the water will tend to cause the concrete over the earth to settle a little more than the concrete over the rock. In order to avoid resulting cracks or to prevent leakage in case they occur, special treatment is recommended by making a strip about 10 ft. wide along the line of division between the earth and rock of concrete reinforced by steel and having a waterproof layer in its lower part. The precise dimensions and features of this strip of reinforced concrete with its course of waterproofing will depend somewhat upon the characteristics of this part of the bottom as developed in the progress of the work, but we recommend that the strip be so designed as to be equivalent in its main features to the following: For a width of about 10 ft., varying perhaps from 8 ft. to 12 ft., according to the sharpness of the rock slope beneath the earth, the concrete shall be at least 8 ins. in thickness (except where portions of the bedrock project into it), with a reinforcement of expanded metal of 3-in. mesh, number 10 gage or heavy wire netting of equivalent strength for about 8 ft. in width, inserted at a distance of 2 ins. below the upper surface. Within this 10-ft. strip of 8-in. concrete, a waterproof course should be laid 2 ins. above the bottom of the concrete, with a width 2 ft. greater than that of the steel reinforcement. This waterproof course should be composed of alternate courses of burlap or other equally strong fibrous material and layers of hot asphalt mixture, the total thickness of the course being not less than ¼-in. It should extend 1 ft. beyond the limit of the steel reinforcement on each side. This reinforced and waterproofed strip of concrete should be so located that about two-thirds of it will come over the earth and one-third over the rock surface.

IN GENERAL.

The details of putting this entire concrete bottom in place other than those already specified must be determined after careful study by the engineer of all the conditions attending the work. Among these details are such matters as laying the concrete in continuous sheets or in square with asphalt or other joints; the use of expanded metal or equivalent heavy wire netting along the joint where fresh concrete may join that which has become set; the thorough cleaning, roughening and wetting of such joints between new and old work, and other similar questions. With the limited time at its command, the Commission has not been able to give sufficient consideration to this class of details, but we desire to make plain the pressing necessity of adopting such details and means of construction as will eliminate so far as possible shrinkage or settlement cracks.

No concrete bottom should be laid over either the rock or the earth until so large a proportion of the total area has been prepared as prescribed above that the work of putting in place the concrete (with the steel reinforcement and waterproof layers where needed) can be prosecuted continuously. The preparation of no definite area is prescribed as that is one of the elements of the work which may be reserved for the judgment of the engineer, but it is the opinion of the Commission that whenever the work of laying the concrete bottom is begun, there should be so much of the total area prepared that this part of the work may be rapidly prosecuted with a large force without hazard or interruption, and that there should be an open space of ample width, not less than 50 to 100 ft., cleaned to sub-grade or to bedrock for inspection and for the purpose of keeping all debris away from the concreting.

In order that shrinkage cracks so liable to take place in large plates of concrete from change of temperature and other causes may be eliminated or reduced to a minimum, freshly laid concrete should be kept well wet and protected from the direct rays of the sun by covering with wet sand not less than 1 in. thick until a sufficient area is formed and set, around which a low temporary dam of earth or other material may be formed so as to permit permanent flooding to a depth of 6 to 12 ins. of water. The Commission regards this treatment of the concrete bottom as fast as it is formed highly essential to the best results.

Along the joint between the concrete bottom and the masonry retaining walls special treatment is required to prevent cracks and leakage. The depth of concrete should here be increased to 18 ins. within 1 ft. of the wall and then brought to the thickness already prescribed within a distance of 6 ft. from the wall. This concrete should be well rammed so as to compact it to the greatest possible extent, thus closing solidly the junction between it and the retaining wall.

Around these portions of the reservoir margin showing a rock bottom where the retaining wall has not yet been constructed its foundation course should be of concrete and it should be so designed as to be completely continuous with the concrete bottom, thus eliminating the joint.

In all this concrete work for the bottom of the reservoir, effective means should be taken to secure the best and the most dense concrete possible under the specifications. To that end, the gravel or broken stone prescribed in the contract should be as well balanced as possible in order to reduce the voids to a minimum, and the mixing should be done with a type of mixer which shall produce the most thorough and intimate admixture of the component parts, the consistency being "wet" rather than "dry."

One member of the Commission is of the opinion that for the portion within 50 ft. of the embankment wall between Gate House No. 2 and the overfall, the pockets and irregularities of the rock bottom should be filled solid with concrete up to the prescribed surface, but for the portion southerly of Gate House No. 3 and over rock bottom, that this width may be diminished to 25 ft. because of the higher natural ground outside the reservoir; further, that all portions showing rock not more than 24 ins. beneath the finished surface, should be treated as rock bottom even when within areas classified as earth portions of the bottom.

He is also of the opinion that 6 ins. of concrete over these portions of the earth bottom more than 100 ft. distant from walls and embankment would probably prove sufficient, but in view of our lack of definite knowledge as to the exact character of the substrata and their tightness, he is not disposed to regard 8 ins. thickness as extravagant.

He offers the further suggestion that if it be possible to to hasten the completion of the walls of the west basin that it could be filled about 10 ft. deep with water during the coming winter, prior to concreting those portions of the bottom more than about 200 ft. distant from the rim of the basin, that careful observations of leakage would probably show the natural bottom so tight, particularly after this pressure of water had washed sand into the crevices and clogged or silted up the cracks, that a less expensive treatment of these interior portions of the bottom would be allowable.

He is further of the opinion that for the best results in tightness and freedom from cracks all of the concrete lining should be put down in alternate squares of about 6 ft. on a side with a 2-in. rebate, or "slip joint" formed at mid depth; this 2-in. offset or rebate to have a slope of about 1-12 and to be covered with asphalt.

EXAMINATION OF THE BREAST OR RETAINING WALLS NOW BUILT.

In accordance with your instructions, we have made detailed and careful examinations of the breast or retaining wall now built between Station 10 and Station 40, also of the similar wall built between approximately Station 50 and Station 56, the latter having been in progress of construction during our visits at the reservoir site. This wall is everywhere 30 ft. or more in height, the elevation of the top of coping being 134 and the finished bottom of the reservoir at about elevation 105; this wall is said to extend down to bedrock at all points. The thickness of the wall under the coping is a little less than 4 ft., while the thickness of its base at the elevation of the bottom of the reservoir is about 15 ft.

It is a rubble wall built of roughly rectangular stones used as excavated from the reservoir site, laid up with Portland cement mortar in the proportions of one volume of cement to three of sand or fine crushed screenings. All means at our command, short of actual removals of portions of the wall, have been employed by us in the examination of this masonry, a considerable portion of which we are informed has not yet received its final pointing.

The stones used in the construction of the wall appear to have been well selected so as to secure the best quality of the rock excavated at the reservoir site. External examination of the wall indicates the Portland cement mortar to be satisfactorily hard and of good quality.

Obviously, it is not possible for us to state precisely the character of the work done in the interior of the completed wall, but on our visits to the reservoir the work of laying up the wall now in progress on the southwest side of the west division has been of excellent quality. One member of the Commission has made frequent examinations of this work in progress, and on every occasion of his inspection that work has been found satisfactory.

In order to test the character of the finished wall between about Stations 10 and 39, i. e., between Gate House No. 2 and the overflow, trenches about 4 ft. deep and 2 ft. wide each about 75 ft. long were excavated at four points and filled with water. These trenches were kept filled for five or six days. The unfilled space back of the walls between about Stations 24 and 26 was likewise filled with water to a depth of about 6 ft., i. e., with the surface of the water at an elevation of about 11 ft. above the bottom of the reservoir. A pond about 600 ft. long probably about 6 ft. in average depth, with top at grade 116.2 or 11 ft. above bottom of reservoir, was also formed between Stations 33.25 and 39. This pond was of clear water, the latter being free of sensible turbidity, yet the leakage was less than in any other stretch of wall tested.

Again, behind the core wall at about Station 88, near the extreme southern end of the east division, a trench about 100 ft. long and 3 or 4 ft. deep was excavated, a vertical interior face of the core wall of about 10 ft. height being there available for observation. The thickness of the core wall at the top was about 3 ft. and a little less than 4 ft. at the bottom of the 10-ft. exposed surface. In all these cases water found its way to some extent through the masonry of the walls.

The head of water in the four trenches back of the breast or retaining wall north of the overflow was about 28 ft. above the bottom of the reservoir; between Stations 24 and 26 it was about 11 ft. In a few cases both in the breast and core walls, there were points where small, thin streams spurted out from the face of the masonry for a few inches. The largest of these was at Station 25 × 60, at elevation 106, near the base of the wall. The water escaping here was measured and the rate found to be about 390 gallons per day of 24 hours. Three other leaks of a similar character but small in amount were measured and found to yield at the rate of about 40 to 60 gallons per day of 24 hours. Where the water oozes or seeps through the porous mortar or masonry in such exceedingly small quantities, it cannot readily be measured, but between Stations 24 and 26, where the rate of leakage was materially higher than at any other point, one member of the Commission estimated the total leakage of this 200 ft. at 1,000 gallons per day of 24 hours, while the other estimated it as equivalent to about half the flow from a common garden hose with a ¼-in. nozzle and 40 lbs. pressure. This particular stretch of wall is said to have been built in winter and is still incomplete, as it has not received its final pointing.

A list of leaks and cracks has been submitted to us as the result of a careful examination of the wall, on Jan. 16, 1902, between Station 10 and Station 37 × 50, and we have carefully examined the wall between the same stations with that list in hand. Few only of the cracks and leaks recorded in that list are now to be found. This is partially and perhaps largely due to the fact that considerable portions of the wall in question have been pointed since the examination of Jan. 16 and that the expansion under temperature changes since that date would have a tendency to close them.

From present appearances, we are unable to give entire credence to the cracks having been of such large dimensions as stated in this list. We have, as a matter of experience, often noted the tendency to overestimate the dimensions of cracks. There is no present appearance of continuity in these cracks to indicate that they are serious as affecting the tightness or stability of the wall.

The water leaking or seeping through all these walls, both breast and core, during our examination, wetted the front faces opposite where the trenches were made, and gave the appearance of the passage of considerable water. As a matter of fact, as our measurements have shown, the actual amount of water passing was so small as not to be serious. That portion of wall between Stations 24 and 26 appears to pass more water than it should, and it is possible, inasmuch as that portion of masonry was laid in winter, that the weather was so cold as to make water-tight work impracticable, or that the inspection was lax. This indicates the difficulty experienced in attempting to lay water-tight masonry in freezing weather and that it is unwise to make the attempt.

We do not find that any of the walls need other treatment than that of extending the trenches, filling them with water, marking the points where the leaks appear, cutting out the mortar joints around those cracks as required by the specifications, and carefully refilling them and pointing all joints not yet complete. A number of points have already been so marked and are apparently to be treated in that manner.

We recommend that this work of repairing defective joints and pointing be thoroughly and carefully done, after which the walls may be considered in suitable condition for the performance of their duty.

It is to be remembered in connection with this part of our work that it is practically impossible to build rubble walls of the dimensions of these walls with the shape and size of stones used and with the head of water behind them, in the usual manner of constructing such masonry, which will be absolutely water-tight. This is an observation which is justified by engineering experience.

It is our judgment that the rock back of these walls should have been excavated so as to make the face approximately vertical and with such an alinement that the back of the wall would have been bonded to the rock face. As it is, a space is left between that face and the back of the wall which should be filled and puddled with the best quality of puddle material and with the greatest care. This does not appear to have always been the case. We recommend that this puddled back filling be done with such good quality of material and abundance of water as to attain the best possible results from the bottom of the back filled space to the top of the wall.

SCREENINGS FOR MORTAR.

Under instructions transmitted to us from you, we have made an extended examination and a considerable number of tests of the fine crusher screenings of the rock excavated at the Jerome Park Reservoir which has for some time displaced sand in the production of mortar and concrete in the masonry work built there. The specifications require only "clean, sharp sand free from loam." We find in the earlier stages of the work that sand excavated at the reservoir site was used under this specification, but that within the past year or two, fine crusher screenings from the rock broken there have been used instead of sand.

This procedure, i. e., using so-called "stone dust" instead of sand in mortar and concrete is not new. The old English authorities on Portland cement and its uses, John Grant and Henry Reid, who published their works nearly 25 and 30 years ago, even then set forth the excellence of fine crushed rock in place of sand for mortar. Since that time it has been used in many places both in this country and in Europe, and especially in this country, on a considerable number of large and important works by some of the most careful and progressive civil engineers. It was used by Mr. George F. Deacon, Engineer for the great Vyrnwy Dam of the Liverpool Water-Works in that structure. He states in a paper read before the Institution of Civil Engineers of Great Britain in 1896: "It is satisfactory to know since its successful employment on the Vyrnwy Works, the use of crushed rock as a material for mortar and concrete making has much increased both in Great Britain and abroad." The same material has lately been used by the Engineer Officers of the army in harbor works at Portsmouth, N. H., and Boston. Mr. G. J. Grisenauer, the cement tester for the Chicago, Milwaukee & St. Paul Railway Company, has investigated the same subject, and found substantial advantage in the use of limestone crusher dust. Fine crusher screenings have been successfully used in the place of sand during the past two or three years in the extensive breakwater work for the harbor of Buffalo. It was also used for the same purpose in the concrete for the Forbes Hill Reservoir of the Metropolitan Water-Works of Boston and has been substituted for sand on account of the marked advantages attending its use in the East Boston Tunnel work. A higher price is paid for fine screenings for the latter work than would be necessary for sand fulfilling the requirements of the specifications. A large number of other modern works might be cited in which "stone dust" has been employed both on account of the increased strength of the mortar and its enhanced tightness.

In order to test the particular materials in question, we have had Mr. A. Black, a member of the instruction force of the Department of Civil Engineering of Columbia University, take about a cubic foot of fairly representative fine screenings from the Jerome Park Reservoir. He has marde a large number of briquettes of standard form and dimensions from that lot of screenings, using Atlas Portland cement, as a supply of that cement was on hand at the University laboratory. These briquettes were tested in tension at ages of one, seven and twenty-eight days with results given in the accompanying table, the proportions of screenings and cement being as shown and as used under the specifications for the reservoir.

Material.	Proportion of sand to cement by volume.	Ult. tensile resistance, lbs. per sq. in. 1 day. Max.	1 day. Mean.	1 day. Min.	7 days. Max.	7 days. Mean.	7 days. Min.	28 days. Max.	28 days. Mean.	28 days. Min.
Cow Bay sand	2 to 1	146	107	73	396	364	310	565	530	518
" "	3 " 1	41	37	21	251	228	212	324	311	300
Fine screenings	2 " 1	125	92	79	371	330	244	541	528	502
" "	3 " 1	52	39	30	255	223	203	412	394	377
Sand from reservoir	2 " 1	94	86	80	292	275	254	...	...	...
" " "	3 " 1	35	29	24	134	122	109	...	...	...

At a subsequent date we also instructed him to proceed to Jerome Park Reservoir and secure about a cubic foot of sand which should be as nearly as practicable representative of the sand used prior to the substitution of the fine screenings or "stone dust." Briquettes similar to those made from the fine screenings have also been made with this sand and tested at the ages of one day and seven days, the period of 28 days not yet having elapsed for the next set of briquettes. The results of testing these last briquettes will be reported later. The table shows the greatest, mean and least results for sets of six or seven briquettes and for each mixture and age. In order to make a comparison with probably the best sand used in this vicinity, briquettes were also made with Cow Bay sand, the ultimate tensile resistance of which are also shown in the table. The results belonging to the fine screenings are all excellent, although somewhat less than those belonging to the Cow Bay sand for one day; they are nearly equal in the seven-day tests. The briquettes made with the sand from the reservoir show results in all cases considerably below those belonging to the fine screenings.

Some of the rock crushed at the Jerome Park Reservoir contains a little mica, while other portions contain none at all. The presence of mica in the fine screenings is prejudicial, but a careful examination (including an examination under the microscope) shows that there is very little mica in the fine screenings used there, so small indeed that it has no material effect upon the strength of the resulting mortar or concrete, as is shown by the results in the preceding table. In crushing rock for the fine screenings micaceous material should carefully be excluded.

These fine screenings are shown on examination to be entirely free from dirt; they constitute in reality an artificial but clean, sharp sand with a range in size of grain from fine to coarse. This variety in size of grain is one of the special advantages possessed by finely crushed rock. The small grains partially fill the voids between the larger, and thus with a given quantity of cement both resistance and water-tightness are increased.

The results of the examination of the fine screenings at the Jerome Park Reservoir show that they may be properly and satisfactorily used in place of sand for that work both in mortar and concrete.

THE CAUSE OF THE CEMENTING VALUE OF ROCK POWDERS AND THE PLASTICITY OF CLAYS.*

By Allerton S. Cushman.†

In the course of the investigation of rocks as road-building material, it early became apparent that in addition to the hardness, resistance to wear, and other physical, mechanical, and economical conditions that required consideration, the binding power, or as it has come to be called, the cementing value, was one of the most important factors in deciding as to the nature and value of the material.

The description of methods of reducing the materials to powders, the formation from these powders of briquettes under constant pressure, and the subsequent impact testing by which the cementing value is obtained, has already been thoroughly described by Mr. L. W. Page,‡ to whom the development of the study of the cementing value of rocks and the methods of impact testing is due.

The tests on many hundred samples, including clays, gravels and rocks of every description have shown a range of cementing values varying from those which will stand several thousand blows down to those that will barely stand one. A careful scrutiny of recorded tests in connection with the nature and chemical composition of a given material does not reveal the reason for the phenomenon. Rocks which, on chemical analysis, show themselves essentially identical in composition frequently vary widely in cementing value.

We are at once reminded of the great variation in plasticity which has been found in the case of clays. That the plasticity of clays is a phenomenon allied to, if not identical with, the binding power of rock dust there seems to be no doubt. The same property which makes a rock dust bind makes it form a plastic mass when worked up with water. It has never been positively decided whether there is a definite combination constituting the essential basis of all substances to which the name clay is applied. If there is, however, one quality which marks and characterizes a clay and distinguishes it from other finely divided material found in nature, it is plasticity. The classification of materials, according to the size of the particles into silts and clays, is in the opinion of the writer incorrect. Powdered glass in the finest state of subdivision in which it can be obtained by elutriation

*Condensed from a paper read before the American Society for Advancement of Science.

†Road Material Laboratory, Dept. of Agriculture, Washington, D. C.

‡Report Massachusetts Highway Commission, 1900.

has no cementing value whatever, and the same thing is true of the powders obtained from the natural glasses and semiglasses represented by some of the igneous and metamorphic rocks.

If we compare a plastic powder with a non-plastic one, nothing is explained when we say that in the former case the particles cohere, while in the latter they do not. The problem still remains to discover, if possible, the reasons for this cohesion. No adequate explanation of the plasticity of clays has as yet been advanced. So high an authority as Dr. Heinrich Ries has left the subject open by his statement that: "Plasticity, whatever its cause, is an important property from a commercial standpoint and interesting from a scientific one."

CEMENTING VALUE OF ROCK POWDERS.

It was realized from the beginning of the investigation that the phenomenon of the cementing power of rock dusts was possibly the result of several if not many causes. Among those which might be expected to have more or less influence, may be mentioned: (1) Solubility, however slight, of the material or of certain ingredients of the material. (2) Size and shape of the particles. (3) Chemical reactions set up on moistening the powders, as, in the cases of Portland cements, mortar, etc. (4) Crystalline forces operating under either (1) or (3) as in the cases of plaster-of-Paris, mortar, cements. (5) Physical nature or condition of the particles and their relations to water: (a) Unbound water; (b) hygroscopic water; (c) water of crystallization; (d) water of constitution, or combination.

After many experiments in this laboratory, some of which are detailed in the following pages, the conclusion was reached that, although the causes put down under the first four headings are to a certain degree operative in many cases, and even perhaps of paramount importance in exceptional ones, it is under the fifth heading that the true cause of cementing power and plasticity must be sought.

If a rock powder is ignited at a temperature at which all the water of combination is expelled, the cementing power is invariably totally destroyed. This is also true as regards the plasticity of all grades and varieties of clays. No better indication could be had that the binding power is a function of the combined water or of some condition of the particles which is invariably accompanied by the presence of combined water. Early in the investigation the idea had suggested itself that there must be a physical difference in the nature of the particles. Powders which cement well, must be composed of particles which present to one another more or less "sticky" or adherent surfaces. As a matter of fact, a trained eye can at once detect a powder that is likely to give a high cementing value. A plastic powder when poured on a flat surface will form a more or less cone-shaped heap, while a non-plastic powder, to use the language of the clay worker, "squats." Most authorities have rejected the notion that water of combination conditions the plasticity, for the simple reason that many totally non-plastic earthy deposits and minerals have a high water content. The difficulty has probably arisen from a failure to distinguish different kinds of water of combination. The whole question of combined water in inorganic materials is a most interesting one and will be more fully discussed later on.

COMPRESSIBILITY OF ROCK POWDERS.

Some rock powders are apparently more compressible than others. In so far as the writer is aware, little or no attention has been given to the subject of the compressibility of rock powders; it is not even known what bearing water of combination has on the volume relations of powders. In order to pursue this subject, it was decided to further investigate. Portions of the rock powders were ignited at a red heat heat until completely dehydrated; a series of briquettes were then prepared by weighing exactly 20 grams of each of the powders, both raw and ignited. These briquettes were then carefully measured and determinations of the specific gravity of the powders made. The results are contained in the following table:

No.	Water %.	Sp. gr.	Height of 20-gram briquette.	Cementing value.	Compression.
441	5.20	2.3	22.2	297	7
441 ignited..	0.00	2.5	29.0	2	—
341	4.73	2.5	21.2	101	2.8
341 ignited..	0.00	2.6	23.2	2	—
342	3.00	2.5	23.8	74	2.4
342 ignited..	0.00	2.5	27.0	2	—
414	0.20	2.5	26.6	2	—
414 ignited..	0.00	2.4	28.9	2	0.2

An inspection of the above table shows that the briquettes made from ignited powder are invariably larger than those made from raw powder, and that this difference in height is not entirely accounted for by the slight difference in specific gravity. Assuming that the water of constitution is so included in the particles of the raw powder as not to add materially to their bulk, a correction must be applied for this. For instance, in the case of No. 441, 5.2% of the 20 grams weighed, or 1.04 grams, consisted of combined water. In No 441 ignited, this proportion of the weight is substituted by material which certainly adds to the volume. In this table the values in the column headed Compression are obtained by applying corrections for the change in specific gravity and loss in water.

It appears from these results, which have been confirmed by many others not here given that plastic powders molded into briquettes under a given pressure apparently suffer a certain compression which is not shown by the material after the plastic condition has been destroyed by ignition. We have now to inquire if any reason can be found not only for this compression, but for the fact that it seems to accompany the plastic condition.

Compressibility may be condition by: (1) Porosity and plasticity of the particles which would allow of their being "squeezed" into closer contact and configuration. (2) Shape and size of the particles governing their resistance to close contact and the inclosure of voids.

In this work it was found that the ignited powder always contained a much larger proportion of impalpably fine dust than the raw hydrated powders. This is shown not only by microscopic examinations but proved by dropping the respective powders into water, when it is easily seen that the former contains a greater proportion of fine material which remains longer in suspension.

It is conceivable that a hydrated material may possess a porosity so fine that the magnitude of the interstitial spaces is submicroscopic, perhaps not far removed from that of the water molecules themselves. The heating by ignition of a powder consisting of such hydrated particles would have a bursting or disrupting effect upon the particles which would thus fall down to a more impalpable dust.

In order to investigate the effect of size of particle on the volume of briquettes it was decided to prepare glass powders of different degrees of fineness. A quantity of the best French plate glass was accordingly powdered in the ball mill and sifted through a 0.25-mm. mesh screen.

Sample.	Approximate size of glass powders, mm	Amount of water used in making briquettes, cc.	Height of briquette, mm.	Cementing value.
Coarse..	maximum 0.2	4	29	1
	average 0.025			
Medium..	maximum 0.050	4	34	1
	average 0.017			
Fine....	maximum 0.012	4	36	1
	average 0.004			

If the glass is crushed to fragments these fragments can be compressed to a certain degree by a given pressure; if we break these fragments still smaller, the resulting fragments, however tiny, are made up of particles arranged in more compact order and in less space than they could be arranged again if once set free. From purely theoretical consideration, therefore, we may say that in reducing the fineness of a powder we are approaching an ideal condition of unit particles which cannot be forced by any ordinary pressures into the same space they occupied as part of fused masses. Whatever the proper explanation of these results may be, it is certain that an increase in the amount of impalpable dust of the smallest possible magnitudes apparently decreases the compressibility of the material by a given pressure. Turning again to the results on rock powders we are led to the conclusion that the driving off of water of combination breaks up the particles to a finer dust, also that this destruction of the particles leads to loss of plasticity.

RELATION OF CEMENTING VALUE TO WATER OF COMBINATION.

As there were on hand in this laboratory a large number of thoroughly air-dried samples of rock powders and clays, of which the cementing value was known, it was decided to determine the water content of these, with a view to seeing if indeed any relation could be traced between cementing value and water of combination. The determinations were made by igniting the powders in a platinum boat contained in a hard glass tube and absorbing the water set free in a weighed sulphuric acid bulb-tube. The results are contained in the following tables:

DOLOMITES AND LIMESTONES.

No.	Cementing value.	Water, %.	Name.
451.....	9	0.40	Dolomite.
665.....	10	0.30	Dolomite.
537.....	10	0.50	Dolomite.
663.....	12	0.35	Limestone.
489.....	13	0.14	Calcite.
470.....	16	0.48	Dolomite.
487.....	26	0.38	Limestone.
343.....	32	0.40	Dolomite.
515.....	38	0.40	Limestone.
664.....	41	0.40	"
503.....	54	0.58	"
666.....	58	0.66	"
347.....	95	0.34	"
424.....	99	0.64	"
336.....	158	1.00	"
361.....	158	2.26	Clay limestone.
462.....	161	1.20	Dolomite.
377.....	195	1.20	Limestone.
557.....	595	6.10	Clay limestone.

MISCELLANEOUS ROCKS.

468.....	2	0.00	Gneiss.
580.....	2	0.43	Gravel.
414.....	2	0.20	Metamorphic silicious rock.
499.....	4	0.02	Quartzite.
652.....	8	3.2	Gravel.
451.....	9	0.40	"
465.....	14	0.81	"
651.....	17	1.30	"
372.....	25	0.56	Gneiss.
592.....	41	1.50	Gravel.
342.....	74	3.00	Silicious chert.
536.....	77	0.68	Gravel.
341.....	101	4.73	Gravel.
335.....	110	1.90	Trap rock.
361.....	158	2.26	Calcareous clay.
441.....	297	5.20	Gravel conglomerate.
396.....	327	2.00	Felsite.
534.....	475	5.00	Red clay.
398.....	577	2.50	Rhyolite.

DIABASE TRAP ROCK.

415....	2	0.81			
420....	6	0.81	Low group	Cementing value,	6.60
354....	10	0.84		Water content,	0.82
405....	19	1.14			
350....	19	1.46	Middle group	Cementing value,	25.00
566....	38	1.45		Water content,	1.35
357....	72	1.80			
517....	76	1.67	High group	Cementing value,	87.00
467....	91	2.81		Water content,	2.04
335 110		1.90			

An inspection of these results shows at a glance that high cementing values show a decided tendency to accompany a high water content. At the same time we see that there are several exceptions revealed, and it is probable that an even greater number of results would show other discrepancies, as it is well known that many minerals with high water content do not yield plastic powders. On the other hand, if a certain kind of water of combination invariably accompanies the plastic condition, this active water would be added to the inactive and an explanation furnished, not only for the general tendency, as shown above, but also for the exceptions to it.

A question that naturally arises is how are we to account for the well-known high-binding powers of many homogeneous crystalline rocks such as limestones and dolomites which show a wide range in cementing value. As a matter of fact, pure calcium carbonate has no cementing value whatsoever; this quality is provided by certain hydrated impurities such as silica, ferric oxide or even clay. The amount of these impurities need not necessarily be very large, but the distribution throughout the mass is probably of a very intimate nature. It has long been known to practical road builders that the binding power of many rocks increases as time goes on, under the combined influence of the action of traffic and water. Every potter knows that the plasticity of clay increases under the action of kneading and working with water. In some industries, clay mixtures are stored away for considerable periods under wet blankets. This process is called "sweating" and is believed to be very beneficial. It has lately been suggested that bacterial fermentations are responsible for the improvement in the quality of clays under such treatment. The writer has no data on this subject, but it is well known that many of the nitrifying bacteria flourish in media composed of inorganic colloids, which suggests that the presence of bacteria may be a concomitant rather than the cause of improvement. Experiments in the laboratory have shown that the cementing value of briquettes is increased, if the dough made from a rock dust is allowed to stand for some time before being molded, and it is still more increased, if the dough is kneaded. This is plainly shown by the results of a sample of dolomite that had an analysis as follows: $CaCO_3$, 54.30; $MgCO_3$, 36.20; combined water, 0.48; silica, 3.00; iron and alumina, etc., 7.00. This dolomite is a celebrated road-building material in the locality in which it is found and its most marked characteristic is the way that its binding power increases after it has been upon the road for some time. In the following table, the rock dust was mixed with water and briquettes made at separate intervals; finally a new lot of dust was made to a dough and well kneaded by hand for one hour.

Time.	Cementing value.
At once.....	16
Dough 4 hours old.....	50
" 24 " "	81
" 72 " "	79
" 96 " "	77
" 120 " "	79
" 144 " "	83
" 8 days.....	81
" kneaded 1 hour.....	100

In summarizing the results as presented in this paper it may be said that it has been pointed out: (1) That the cementing power of rock powders is a property similar to the plasticity of clays. (2) That all rock powders that have cementing power show the same peculiar relation to water that is shown by substances that possess an amorphous colloid structure, i. e., they can be dehydrated and rehydrated, until by prolonged high heating, the structure is destroyed.

It is not the intention of the writer to maintain that the gelatinous mass in which silicic acid separates from a dilute solution is in any way comparable to a plastic clay mass. The question is purely one of the condition of the particles which go to make up the mass of plastic rock-powder or clay. In the opinion of the writer, particles which are entirely crystalline in their nature have nothing to do with plasticity except to act as a diluent. It is the amorphous particles which, by reason of their characteristic structure, are able to absorb water and assume the condition which causes them to exhibit that coherence which in the mass we denominate plasticity.